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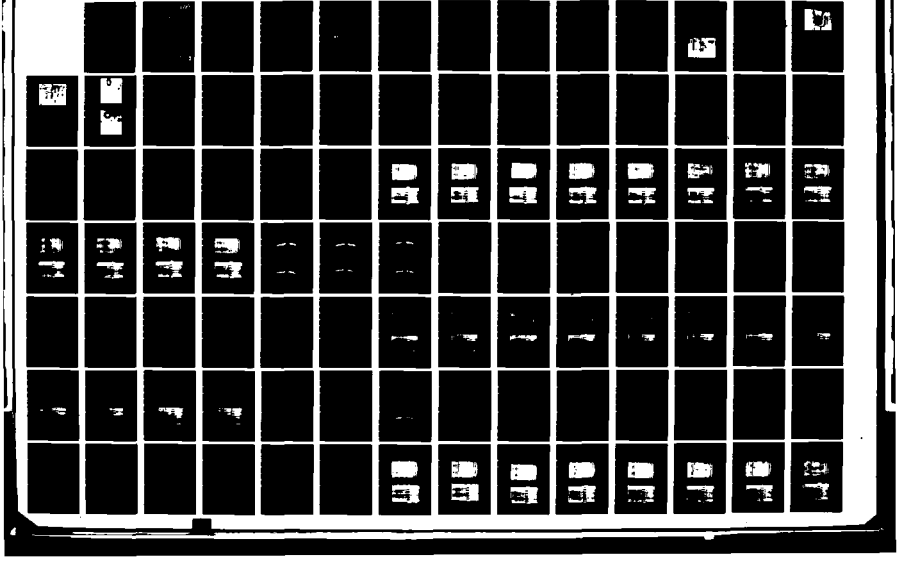

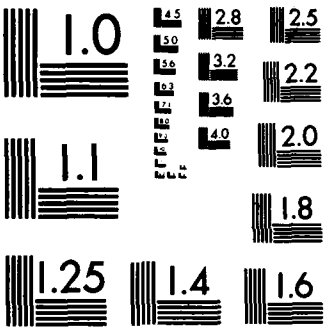

EVALUATION OF FOUR LUBRICANTS USING A MODIFIED FEDERAL TEST METHOD 354 TEST PROCEDURE

INTERIM REPORT
AFLRL No. 122

By

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Under Contract to

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Energy and Water Resources Laboratory
Fort Belvoir, Virginia

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19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

Detroit Diesel 6V-53T	MIL-L-2104
FTM 354	MIL-L-46167
Cast Iron Block	Aluminum Block

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

Four 100-hour engine tests were conducted using the Detroit Diesel 6V-53T engine. Federal Test Method 354 was utilized for these tests with the cast iron block version of the 6V-53T engine used instead of the aluminum block version. Test lubricants were AL-8925-L, AL-9841-L, AL-10153-L, and AL-8980-L, designated as Oils A, B, C, and D in the report.

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FOREWORD

The work reported herein was conducted at the U.S. Army Fuels and Lubricants Research Laboratory located at Southwest Research Institute, San Antonio, TX, under Contracts DAAK70-80-C-0001 and DAAK70-82-C-0001, during the period August 1980 through December 1981. The contracting officer's representative was Mr. F.W. Schaekel, Energy and Water Resources Laboratory, USAMERADCOM, DRDME-GL, Ft. Belvoir, VA, and the technical monitor was Mr. Tom Bowen of the same office.

ACKNOWLEDGEMENTS

The authors wish to thank Mr. Richard Moon for the supervision and preparation of the tests reported herein.

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I. INTRODUCTION

Federal Test Method (FTM) 354 was developed to evaluate the performance of Arctic engine oils in high-output diesel engines.(1)* This test method(2) used the aluminum block version of the Detroit Diesel 6V-53T engine, and proved to be effective in discriminating lubricant quality under high-output conditions. Because the 6V-53T engine is no longer available in the aluminum block version, the four tests reported herein were conducted using the cast iron version of the 6V-53T engine. The test setup for the four tests differs in several respects from FTM 354. These differences are described in Section III of this report.

II. OBJECTIVE AND SCOPE

The objective of this work was to determine if the iron block version of the 6V-53T engine could discriminate lubricant quality when run according to FTM 354. Deviations from FTM 354 described in Section III of this report were considered minor when compared to the change from aluminum to cast iron blocks. Due to the limited number of tests run, it was beyond the scope of this report to establish correlations between the aluminum and cast iron tests.

III. EXPERIMENTAL

A. Test Engine Setup

The equipment for this program included a 400-hp Midwest absorption dynamometer, an Eaton Dynamatic control chassis, and a Hagan pneumatic load transmitting/indicating load system. Combustion air was drawn into the engine through a stack of four dry-type automotive air filters inside a fiberglass-

* Underscored numbers in parentheses refer to references at end of report.

lined 30-gallon barrel, used for noise suppression. Exhaust gas was discharged from the engine into a 4-inch ID flexible line and then into a common exhaust system which operated under 6 to 8 inches water vacuum. Treated water for jacket coolant was then circulated by the engine's centrifugal-type water pump, and the engine coolant thermostat was mechanically locked in the open position to provide normal operating flow restriction. Jacket water was cooled by running it through a tube-in-shell heat exchanger. Fuel was brought to the engine directly from a 4000-gallon underground tank. The fuel system was plumbed in such a way that the return fuel (injector cooling fuel) was diverted to the day tank at a position downstream from the mass flowmeter.

Detailed descriptions of the test setup (Figure 1), engine rebuild, engine calibration, operating procedures, and rating method are given in Federal Test Method 354. Several changes were made in the equipment/procedures specified by FTM 354. These changes are:

FIGURE 1. COOLING SYSTEM AND ENGINE SETUP

1. Engine Block - A cast iron version of the 6V-53T engine was used in these tests. The Detroit Diesel model number of the engine is 5063-5395.

2. Engine Coolant - A 50/50 volumetric mixture of a commercial anti-freeze and water was used instead of the coolant prescribed in FTM 354.

3. Oil System - The oil filter assembly was relocated to an off-engine position in order to prevent the filter assembly from vibrating loose. The change from aluminum to cast iron blocks required additional oil-cooling capacity to maintain the correct oil temperature. This was accomplished by using the eight-plate transmission cooler (DD-8539953) in conjunction with the standard sixteen-plate oil cooler (DD-8528885). Figures 2 and 3 depict the layout of the oil system.

4. Fuel System - Two heat exchangers were used to maintain the required fuel temperature as shown in Figures 4 and 5.

5. Blowby System - The change from aluminum to cast iron blocks significantly reduced the amount of blowby emitted by the engine, rendering the blowby meter specified in FTM 354 unusable. To provide an indication of relative blowby, the system shown in Figures 6, 7, and 8 was used. Although this system was not calibrated in standard cubic feet per minute, it served to indicate mechanical engine damage by showing any large increases in blowby. To maintain filter cleanliness, the discharge of the blowby surge tank was not directed into the engine air intake slipstream.

6. Lubricant Inspections - Each sample of engine oil was quantitatively tested for iron content in addition to the tests specified in FTM 354. Each sample was tested in an X-ray fluorescence spectrometer and the results reported in parts per million.

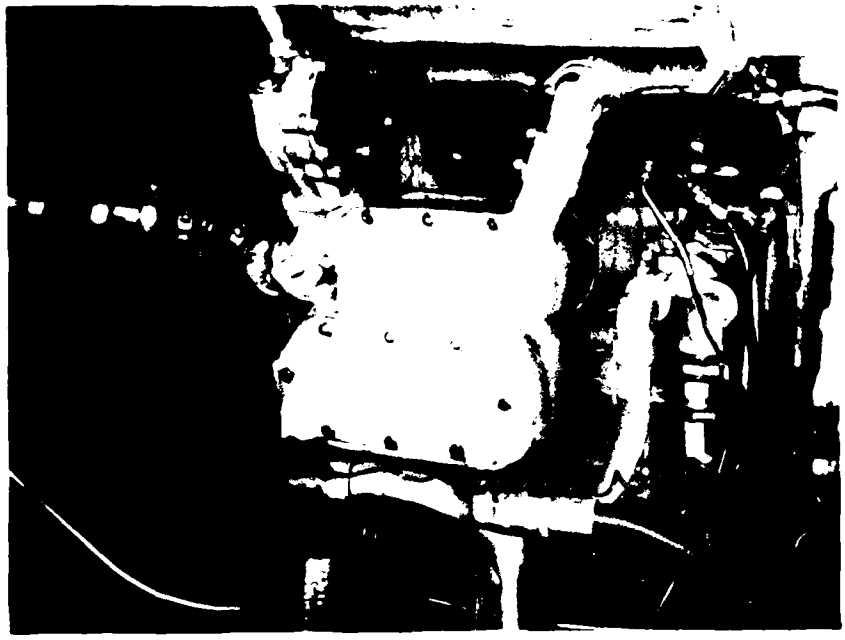


FIGURE 2. ENGINE OIL COOLERS

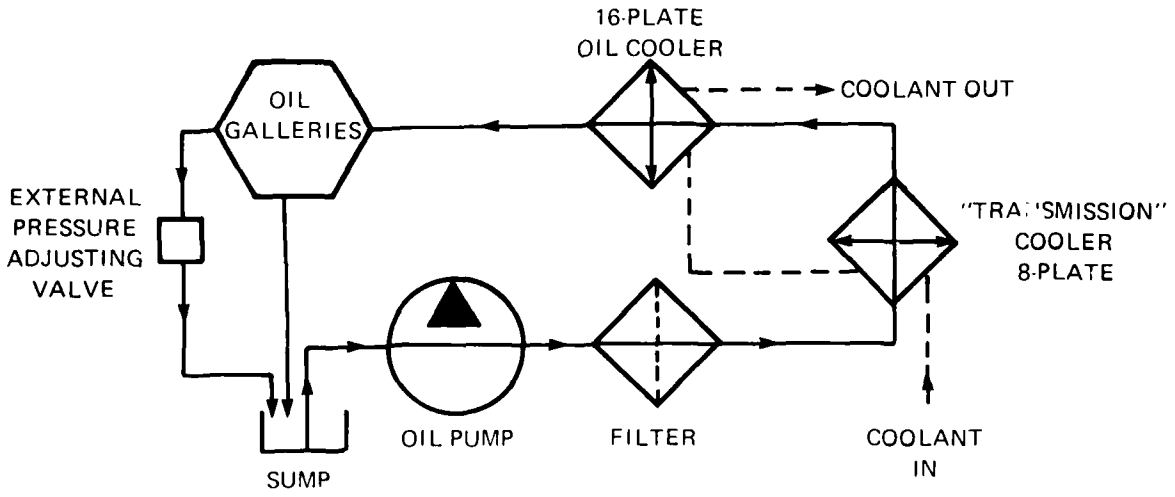


FIGURE 3. OIL SYSTEM SCHEMATIC

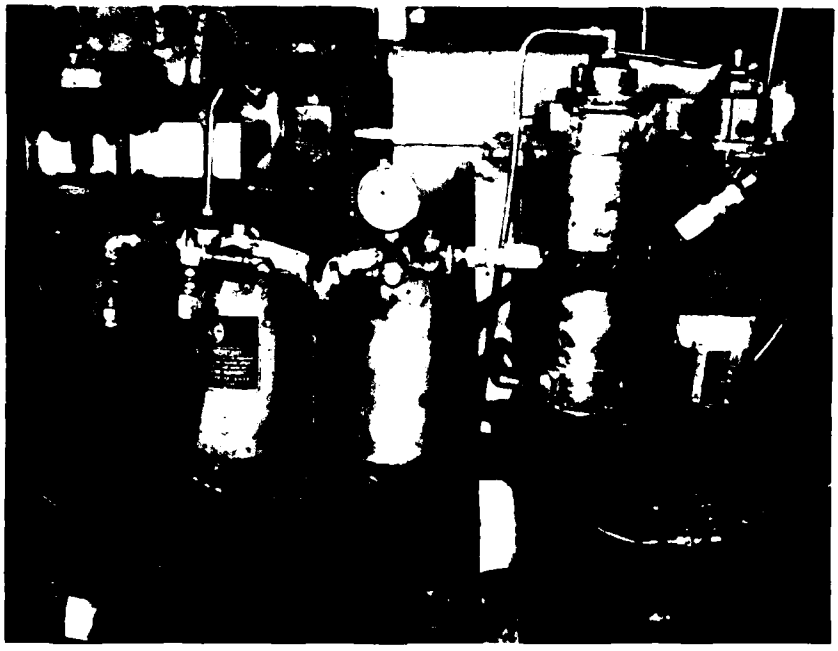


FIGURE 4. FUEL FILTER AND HEAT EXCHANGER SETUP

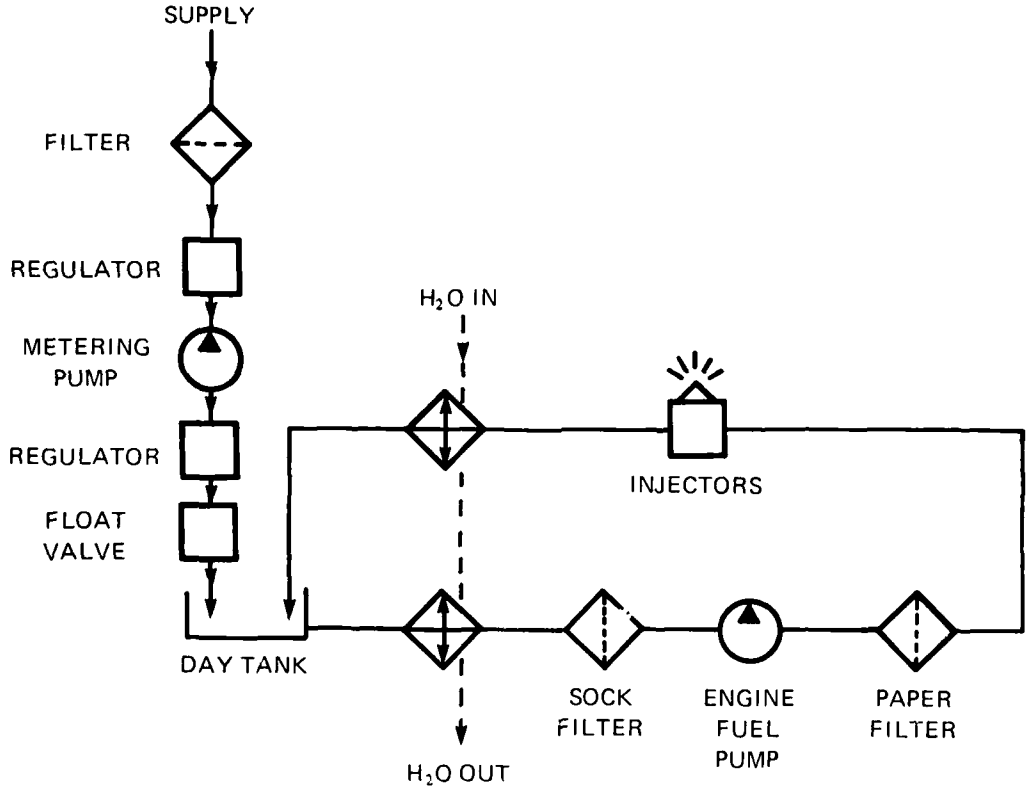


FIGURE 5. FUEL SYSTEM SCHEMATIC

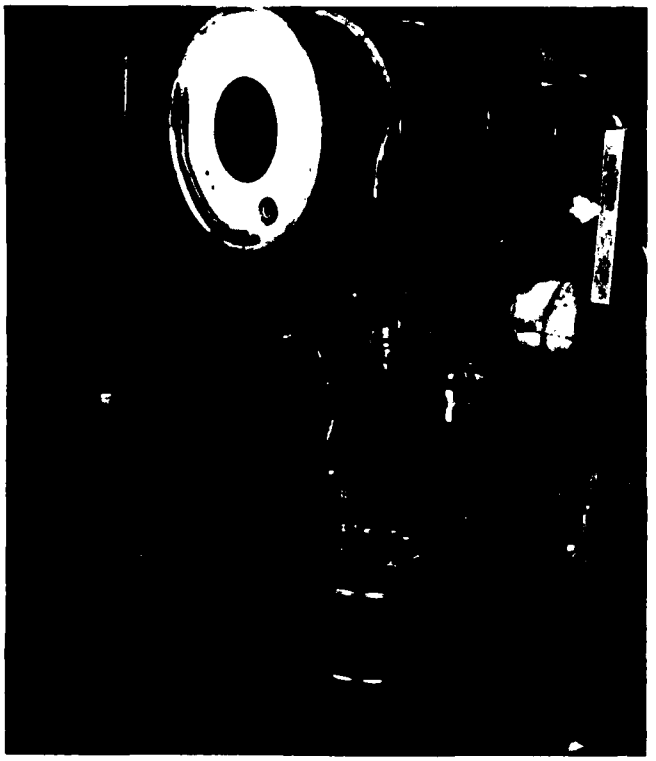


FIGURE 6. BLOWBY SURGE TANK SETUP, SIDE VIEW

FIGURE 7. BLOWBY SURGE TANK SETUP, FRONT VIEW

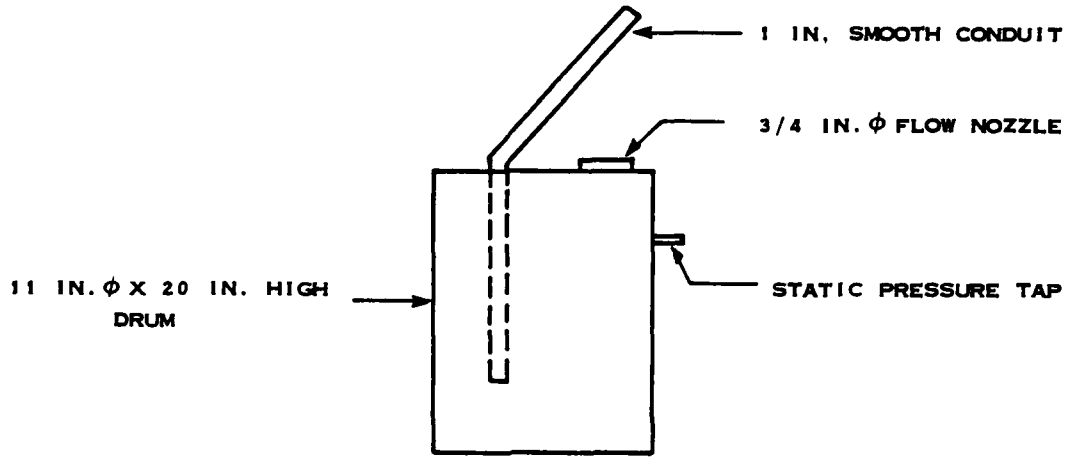


FIGURE 8. BLOWBY SURGE TANK

7. Photographic Data--Black-and-white photographs were taken to document wear parts.

B. Test Fuel

The test fuel used for these tests was CAT 1-H diesel fuel. Typical inspections for this test fuel are given in Table 1 and compared with the requirements of FTM 341.

C. Test Lubricants

The lubricants used in these tests were AL-8925, AL-9841, AL-10153, and AL-8980, designated henceforth as Oils A, B, C, and D, respectively. Properties of the test lubricants are shown in Table 2. Oils A and B were qualified MIL-L-46167 5W-20 lubricants.(3) Oil C was a 10W-30 MIL-L-2104D candidate. Oil D was an SAE 30 grade MIL-L-2104C(4) qualified product which serves as the Army reference oil for MIL-L-2104C.

IV. DISCUSSION OF RESULTS

Test results are presented in Appendices A through D. For purposes of discussion, wear and deposits data have been summarized and are shown in Table 3. These data are represented in graphic form in Figures 9 through 12.

TABLE 1. ANALYSIS OF DIESEL FUEL

Inspection	Test Method	Test Fuel	FTM 341 Requirements
Gravity, °API at 60°F (16°C)	D 287	34.9	Record
Flash Point, °F (°C)	D 93	176 (80)	100 (38) min
Cloud Point, °F (°C)	D 2500	+25 (-4)	Record
Pour Point, °F (°C)	D 97	+5 (-15)	+20 (-7) max
Viscosity 100°F, cSt	D 445	3.21	1.6-4.5
Distillation, °F (°C)	D 86		
IBP		382 (194)	Record
10%		465 (241)	Record
50%		523 (272)	500 (260) min
90%		601 (316)	600-640 (316-338)
EP		671 (355)	650-690 (343-366)
Water and Sediment, vol%	D 1796	0	0.05 max
Ramsbottom Carbon, %	D 524	0.14	Record
Sulfur, wt%	D 1266	0.399	0.35-0.45
Corrosion, 3 hr at 210°F (99°C)	D 130	1a	Pass
Aniline Number, °F (°C)	D 611	153.9 (67.7)	Record
Neutralization No., mg KOH/g	D 974	0.03	Record
Cetane Index	D 976	50	40-45
Lower Heating Value, Btu/lb (MJ/kg)	D 240	18,665 (43.42)	Record

TABLE 2. *PROPERTIES OF TEST LUBRICANTS*

	Test Method	Oils A	B	C	D
AL Code		8925	9841	10153	8980
Viscosity grade		5W-20	5W-20	10W-30	30
Military specification		MIL-L-46167	MIL-L-46167	Candidate MIL-L-2104D	MIL-L-2104C
°API at 60°F(16°C)	D 287	21.3	36.5	29.2	25.2
K Vis at 40°C, cSt	D 445	26.32	29.56	66.39	109.11
K Vis at 100°C, cSt	D 445	5.90	5.75	10.45	11.65
Viscosity Index	D 2270	179	140	145	93
TAN	D 664	0.3	3.1	2.3	2.3
TBN	D 664	5.5	5.3	8.7	13.3
Flash Point, °C	D 92	234	232	202	223
Sulfated Ash, %	D 874	1.45	1.07	1.09	1.60
Barium, ppm (AA)		9055	2200	<50	<50
Calcium, ppm (AA)		5	146	1400	4750
Magnesium, ppm (AA)		1	955	900	30
Zinc, ppm (AA)		0	1400	1270	670
Sulfur, ppm (XRF)		200	4600	5800	6500
Phosphorous, ppm (XRF)		100	1300	963	700

AA = Atomic Absorption Method.
XRF = X-ray Fluorescence Method.

TABLE 3. TEST RESULTS

Test Oil	A	B	C	D
Cylinder Scuffing, %Total RTA	10	15	14	7
Intake Port Plugging, %	2	1	1	1
Ring Groove Carbon Filling, %	11	6	10	8
Cylinder Liner Bore Change, in. x 10^{-4}	-4	8	4	0
Ring End Gap Change, (all rings) in. x 10^{-4}	30	13	5	10
Fire Ring End Gap Change, in. x 10^{-4}	20	40	3	0
Final Oil Iron Content, ppm	23	236	119	18
Piston Weighted Deposits (WTD)	314	210	270	202
Fire Ring Face Distress, %	6	1	12	39
2 & 3 Ring Face Distress, %	17	0	19	5
Oil Consumption, Lb/hr	0.51	0.81	0.51	0.59

RTA - Ring travel area

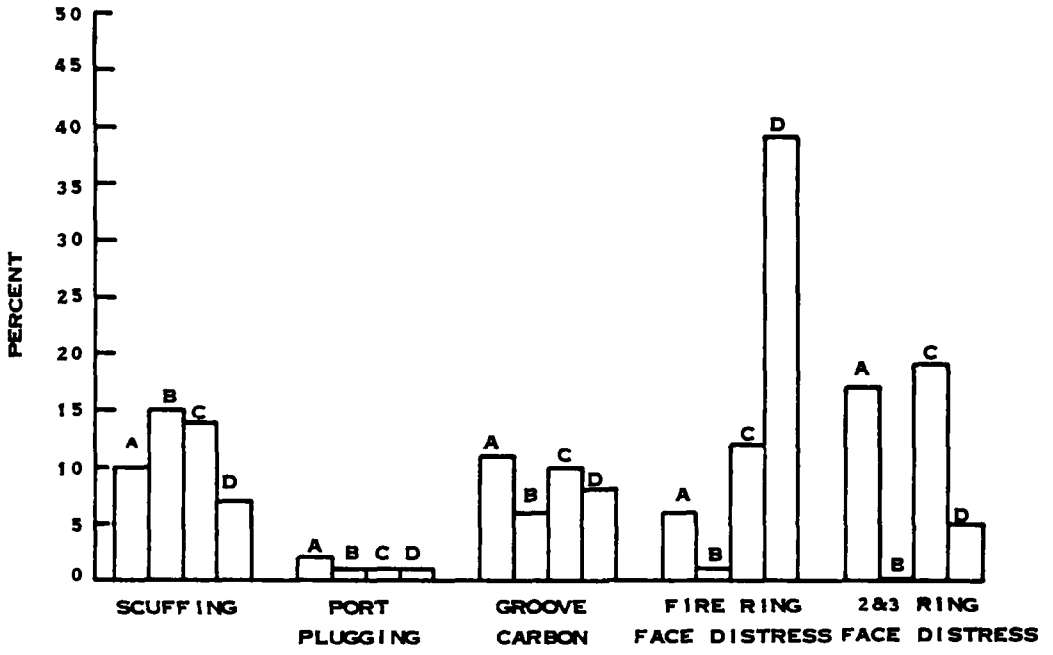


FIGURE 9. SCUFFING AND DEPOSITS

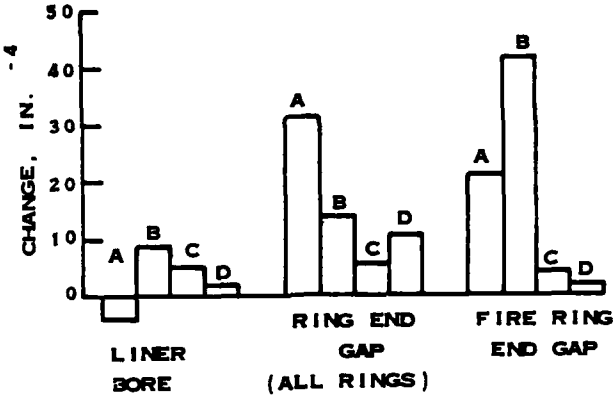


FIGURE 10. MEASURED WEAR

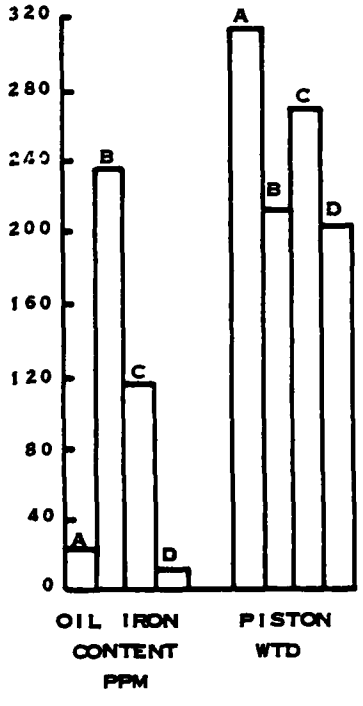


FIGURE 11. OIL IRON CONTENT AND PISTON WTD

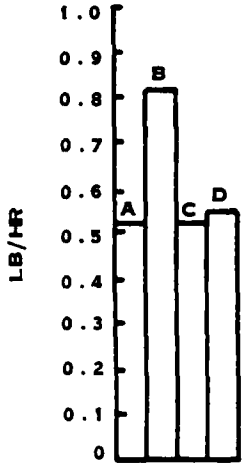


FIGURE 12. OIL CONSUMPTION

From past experience (5,6,7), we would expect oil D to produce better results than oils A, B and C in terms of ring face distress and liner scuffing. We would also expect the performance of oil A to approach that of oil D and to be superior to oil B. Figures 9 through 12 show this expected ranking in terms of liner scuffing but fail to in terms of ring face distress. Fire ring end gap and engine oil content at end of test show the expected ranking, but liner bore wear and ring end gap (all rings) yield ambiguous results. The oil consumption for oil B (0.81 lb/hr) was markedly higher than the other tests and exceeded the FTM 354 validity limit of 0.75 lb/hr. This high oil consumption was probably caused by severe wear of the oil control rings in cylinder 3L. Liner 3L also manifested severe scuffing ratings of 70 percent of the total ring travel area. The severe liner scuffing in 3L should have caused ring face distress in the associated rings. Heavy wear was noted for these rings, but very little ring face distress was seen. The combination of liner scuffing in a heavily oil-bathed area probably produced "mirror-finished" rings. The ambiguous results from this test were heavily influenced by this one liner/piston/ring set. Based on Figures 9 through 12, no clearcut ranking scheme can be established for these lubricants.

V. CONCLUSIONS

Based on this limited number of tests (four), the cast iron 6V-53T engine appears to discriminate lubricant quality when run according to FTM 354 instructions. More cast iron FTM 354 tests will be necessary in order to establish any correlation with standard FTM 354 tests.

VI. RECOMMENDATIONS

More cast iron FTM 354 tests should be performed. Candidate oils should be selected to correspond to existing FTM 354 tests. Each test in this report should be repeated in order to determine repeatability and validity of the data.

VII. REFERENCES

1. Lestz, S.J., "Development of a Diesel Engine Test Technique for Evaluating Arctic Engine Oils," Interim Report No. 24, Government Accession No. AD 768901, U.S. Army Fuels and Lubricants Research Laboratory, Southwest Research Institute, September 1973.

2. Method 354, Federal Test Method Standard 791B, "Performance of Arctic Lubricating Oils in a Two-Cycle Diesel Engine Under Steady-State Turbosupercharged Conditions," January 1973.

3. U.S. Military Specification MIL-L-46167, Lubricating Oil Internal Combustion Engine, Arctic, February 1974; Amendment 1, May 1978.

4. U.S. Military Specification MIL-L-2104C, Lubricating Oil, Internal Combustion Engine, Tactical Service, November 1970.

5. Lestz, S.J., Bowen, T.C., "Development of Army Synthetic Automotive Engine Oils for Arctic Service," Interim Report No. AFLRL 73, AD A019113, Contract Nos. DAAD05-70-C-0250 and DAAK02-73-C-0221, September 1975.

6. Lestz, S.J., Bowen, T.C., "Army Experience With Synthetic Engine Oils in Mixed Fleet Arctic Service," SAE No. 750685, presented at SAE Fuels and Lubricants Meeting, Houston, TX June 1975.

7. Engine Test Report: "Performance of Arctic Lubricating Oils in a Two-Cycle Diesel Engine Under Steady State Turbosupercharged Conditions," Test Lubricant: ME-1 (AL-7022-L), Engine Test Number: 6D8019-8 (Modified Test), Date Completed: 23 November 1977.

APPENDIX A

PERFORMANCE OF AL-8925-L LUBRICATING OIL IN A TWO-CYCLE DIESEL ENGINE UNDER STEADY-STATE TURBOSUPERCHARGED CONDITIONS

PERFORMANCE OF AL-8925-L LUBRICATING OIL IN A TWO-CYCLE DIESEL ENGINE UNDER STEADY-STATE TURBOSUPERCHARGED CONDITIONS (Method 354 Fed. Test Method Std. 791B)

Engine Test Number: MTC 2 (Modified Test*)

Date Completed: 26 September 1980

Conducted For

U.S. Army Mobility Equipment Research and Development Command
Energy and Water Resources Laboratory
Fort Belvoir, Virginia

by

U.S. Army Fuels and Lubricants Research Laboratory
Southwest Research Institute
San Antonio, Texas 78284

*Modified Test

This test used the cast iron block version of the DD6V-53T engine. Changes include a cast iron engine block, a 16-plate oil cooler and an 8-plate auxiliary oil cooler.

TABLE 1

6V-53T 6D-151056
BUILD-UP ENGINE MEASUREMENTS

	Measurements*			
	Min.	Max.	Avg.	Specified Limits**
Connecting rod bearing clearance	0.0036	0.0040	0.0039	0.0010-0.0040
Cylinder liner block bore				
Taper	0.0001	0.0006	0.0002	0.0015 max.
Out-of-round	0.0001	0.0008	0.0003	0.0015 max.
Inside Diameter	4.3566	4.3580	4.3574	4.3565-4.3575 4.3595 max.
Cylinder liners (installed)				
Taper	0.0000	0.0007	0.0003	0.015 max.
Out-of-round	0.0001	0.0007	0.0005	0.015 max.
Inside diameter	3.8753	3.8765	3.8759	3.8752-3.8767
Piston to liner fit[1]	0.0073	0.0089	0.0080	0.0060-0.0095
Piston diameter	3.8673	3.8686	3.8680	3.8669-3.8691
Fire Ring				
End gap	0.029	0.039	0.034	0.020-0.046
Side clearance	0.002	0.004	0.003	0.003-0.006
#1 Compression ring				
End gap	0.026	0.035	0.030	0.020-0.046
Side clearance	0.007	0.008	0.008	0.007-0.010
#2 & #3 Compression ring				
End gap	0.027	0.041	0.033	0.020-0.046
Side clearance	0.005	0.006	0.006	0.005-0.010
Oil rings				
End gap	0.018	0.021	0.019	0.010-0.025
Side clearance	0.0025	0.004	0.0033	0.0015-0.0055

* All measurements given are in inches.
** Wear limits with new liners in a used block.
[1] Thrust-Anti-thrust direction

TABLE 2

OPERATING DATA SHEET

Test Run at U.S. Army Fuels & Lubricants Research Laboratory (SwRI)

Test Oil: AL-8925-L Test Fuel: 1-H CAT

Test No.: MTC-2 Test Stand: 5 Engine No.: 6D-151056

Test Hours: 100 Date Started: 22 September 1980 Completed: 27 September 1980

Total Downtime: 6.42 Hrs Scheduled; 0 Hrs Unscheduled

	Min.	Max.	Avg.
Engine Speed, rpm	2798.0	2802.	2800.
Load, lbs	97.	100.	98.
Output, Bhp	232.	240.	236.
Fuel Rate, lb/min	1.55	1.64	1.60
Oil Consumption, lb/hr			0.5098
Temperature, °F			
Jacket-in	160.	165.	164.
Jacket-out	170.	175.	174.
Oil Sump	231.	239.	234.
Inlet Air (compressor)	84.	108.	97.
Airbox	257.	281.	269.
Exhaust before turbo	790.	840.	816.
Exhaust after turbo	720.	770.	748.
Fuel at filter (secondary)	89.	97.	91.
Pressures			
Compressor suction, in. H_2O	6.2	6.8	6.50
Compressor discharge, psi^2	8.5	9.2	8.77
Blower discharge (airbox), psi	14.9	15.5	15.18
Exhaust before turbo, psi	11.0	11.6	11.29
Exhaust after turbo, in. Hg	1.4	2.0	1.83
Oil gallery, psi	33.0	34.5	34.02
Fuel at filter, psi	70.0	72.0	71.12
Blowby, in. H_2O	0.79	0.91	0.84

TABLE 3

RATING DATA SHEET

Test Run at U.S. Army Fuels & Lubricants Research Laboratory (SwRI)

Test Oil: AL-8925-L, Test Fuel: 1-H CAT

Test No.: MTC-2 Test Stand: 5 Engine No.: 6D-151056

Test Hours: 100 Date Started: 22 September 1980 Completed: 26 September 1980

A. Cylinder Liner Ratings

Intake Port Plugging

Cylinder No.	Restriction, %
1L	1
2L	2
3L	1
1R	1
2R	2
3R	2
Average	1.5

Scuffing, Glazing, and Lacquer*

Cylinder No.	Scuffing, % Thrust	Scuffing, % Anti-Thrust	Scuffing, % % Total Area	Glazing, %	Lacquer, %
1L	5	5	5	5	95
2L	5	5	5	5	95
3L	5	5	5	5	95
1R	10	10	10	5	95
2R	5	5	5	2	98
3R	15	50	32.5	10	90
Average	7.5	13.3	10.4	5.3	94.7

* Total Ring Travel Area

B. Piston Ratings

Ring Sticking and Condition**

Cylinder No.	Ring Fire	Ring No. 1	Ring No. 2	Ring No. 3
1L	F- 5	F-N	F-N	F-N
2L	F- 5	F-N	F-N	F-N
3L	F+- 2	F-2	F-2	F-2
1R	F+- 2	F-1	F-10	F-1
2R	F@- 1	F-1	F-1	F-1
3R	F#- 20	F-85	F-100	F-100

** Numbers denote % area ringface burn.
+ What appears to be burning is actually carbon deposit plus 2% burn.
@ What appears to be burning is actually carbon deposit plus 1% burn.
# Partially collapsed.
F = Free N = Normal

TABLE 3 (Cont'd)

Ring Groove Carbon Filling and Oil Groove Lacquer

Cylinder No.	Groove Filling, %				Oil Groove Lacquer (Demerit)	
	Fire	No. 1	No. 2	No. 3	Upper	Lower
1L	10	20	0	0	4	4
2L	10	35	2	0	4	4
3L	5	15	3	0	4	4
1R	10	20	3	0	4	4
2R	10	85	2	0	4	4
3R	15	20	5	0	4	4

Land Description

Cylinder No.	Description
1L	Normal
2L	Normal
3L	Normal
1R	Normal
2R	Normal
3R	Normal

Skirt (Demerit)

Cylinder No.	Thrust	Anti-Thrust
1L	6.0 Lt Scratches	6.2 Lt Scratches, 10% Lt Scuff
2L	6.8 Lt Scratches	6.5 Lt Scratches
3L	5.8 Lt Scratches	5.8 Lt Scratches
1R	6.0 Lt Scratches	5.5 Lt Scratches
2R	6.0 Lt Scratches	5.7 Lt Scratches
3R	5.8 Lt Scratches, 10% P. Melt	6.0 Lt Scratches

C. Other Ratings

Combustion Chambers With Exhaust Valves

Cylinder No.	Description
1L	15%B-60%A-20½%½A-5%½A
2L	10%B-80%A-10%½A
3L	5%B-70%A-10%½A-15%½A
1R	90%A-10%½A
2R	15%B-70%A-10%½A-5%½A
3R	5%B-85%A-5%½A-5%½A

TABLE 3 (Cont'd)

D. Interim Inspections

Zero Test Hours	Inspection	Zero Test Hours	Inspection
1L	Normal	1R	Normal
2L	Normal	2R	Normal
3L	Normal	3R	Normal

24 Test Hours	Inspection	24 Test Hours	Inspection
1L	Normal	1R	Normal
2L	Normal	2R	Normal
3L	Normal	3R	Normal

48 Test Hours	Inspection	48 Test Hours	Inspection
1L	Normal	1R	Normal
2L	Normal	2R	Normal
3L	Normal	3R	N al

72 Test Hours	Inspection	72 Test Hours	T- pection
1L	Normal	1R	Normal
2L	Normal	2R	Normal
3L	Normal	3R	Normal

E. Legend

Abbreviations	Definitions
T-Side	Thrust side of cylinder liner or piston skirt. (Inboard left bank and outboard right bank).
AT-Side	Anti-thrust side of cylinder liner or piston skirt (Side opposite thrust side).
Lt	Light
Med	Medium
Hvy	Heavy
P. Melt	Melting of the plating on the piston surface.
Sct	Scratching
Frt	Front of piston or liner
Rt	Rear of piston or liner
Normal	All components considered normal, unless specified otherwise. This means rings are free, only light scuffing of liner and piston skirts, hard carbon on fire lands and lacquer on other ring lands.

TABLE 4

OIL ANALYSES DATA SHEET

Test Run at U.S. Army Fuels & Lubricants Research Laboratory (SwRI)

Test Oil - AL-8925-L Test Fuel 1-H CAT

Test No. MTC-2 Test Stand 5 Engine No. 6D-151056

Test Hours 100 Date: Started 22 September 1980 Completed: 27 September 1980

Determination	New Oil	Test Hour Sample 12	24	36	48	60	72	84	100
Viscosity, cSt									
at 40 °C			28.1		28.4		28.5		28.7
at 100 °C			6.22		6.30		6.34		6.38
Total Acid Number	.296		0.17		0.14		0.18		0.17
Total Base Number	5.54		4.54		3.59		3.34		2.84
Sulfated Ash, %			1.58		1.56		1.69		1.71
Flash Point, °C			242.		238.		242.		233.
Iron Content, ppm		16.	15.	18.	18.	15.	21.	19.	23.
Carbon Residue, %			1.70		1.81		1.89		2.03

TABLE 5

Lubricant: AL-8925-L

WEAR MEASUREMENTS

Cylinder Liner Bore Diameter Change*

	Cylinder Number 1L		2L		3L	
	T-AT**	F-B**	T-AT	F-B	T-AT	F-B
Top	+0.0007	-0.0005	+0.0004	-0.0002	+0.0009	-0.0006
Middle	0.0000	-0.0002	0.0000	-0.0002	+0.0002	-0.0002
Bottom	-0.0003	-0.0001	-0.0001	-0.0004	-0.0003	+0.0001

	Cylinder Number 1L		2L		3L	
	T-AT	F-B	T-AT	F-B	T-AT	F-B
Top	+0.0004	-0.0005	-0.0001	-0.0002	+0.0002	-0.0002
Middle	0.0000	-0.0001	0.0000	-0.0002	+0.0001	+0.0001
Bottom	-0.0002	-0.0001	-0.0003	-0.0001	-0.0003	-0.0002

Average Change

	T-AT	F-B
Top	+0.0004	-0.0004
Middle	+0.0001	-0.0001
Bottom	-0.0003	-0.0001

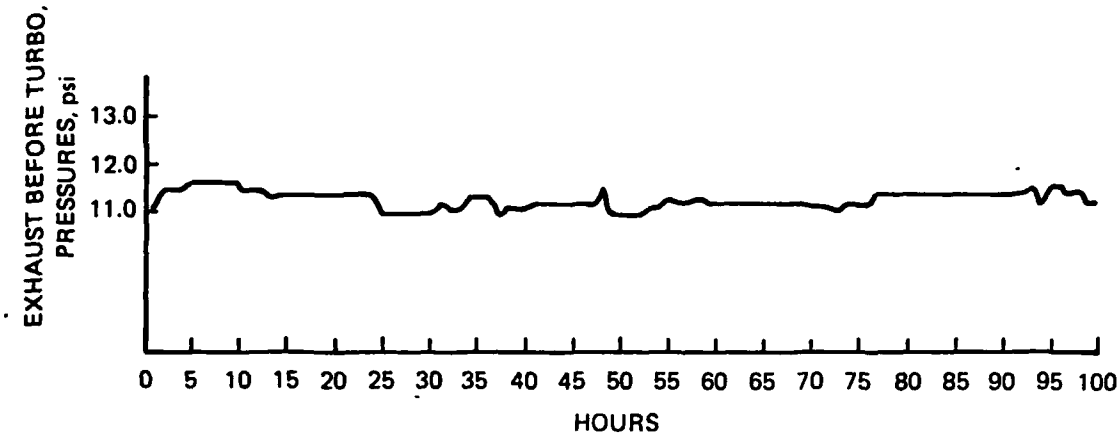
Overall Average Change: -0.0004

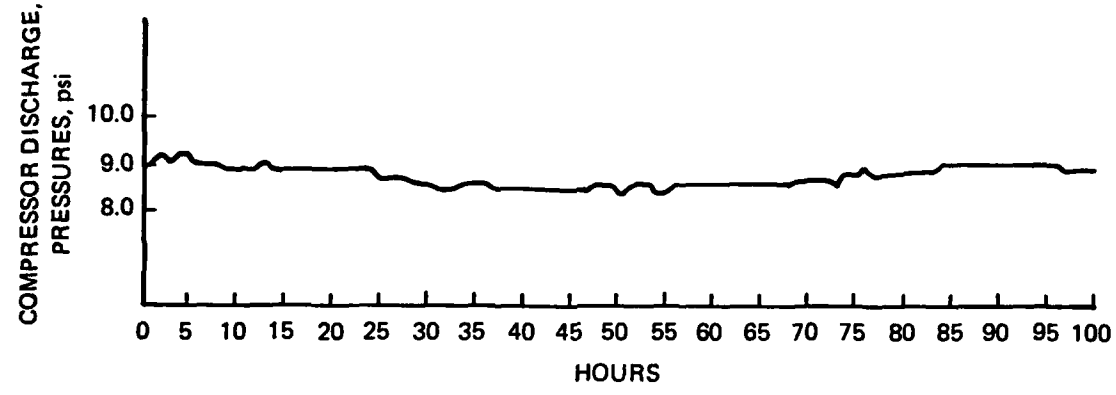
Piston Ring End Gap Change

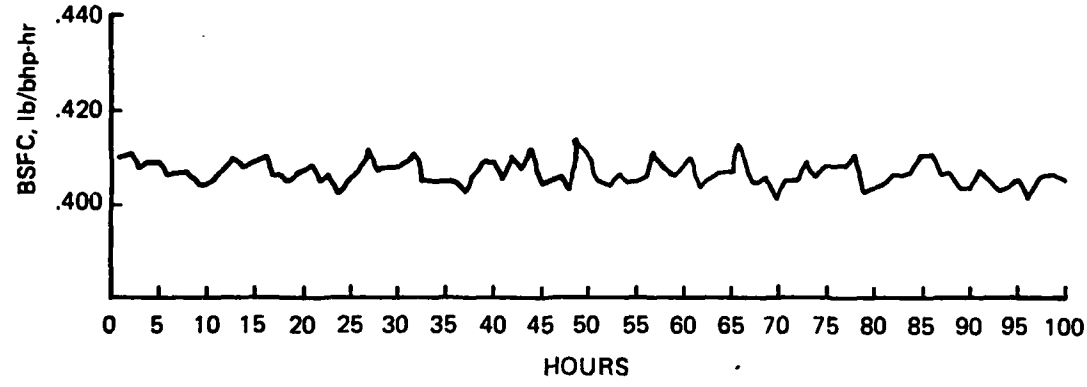
Ring Number	1L	2L	3L	1R	2R	3R	Average Change
1	+0.001	+0.002	+0.002	+0.003	+0.003	+0.001	+0.002
2	+0.003	+0.001	+0.001	+0.001	+0.003	+0.001	+0.002
3	+0.002	+0.001	+0.002	+0.001	+0.001	+0.001	+0.001
4	+0.001	+0.001	+0.001	+0.004	+0.001	+0.003	+0.002
5	+0.003	+0.005	+0.007	+0.005	+0.002	+0.007	+0.005
6	+0.005	+0.005	+0.003	+0.004	+0.005	+0.005	+0.005
7	+0.005	+0.005	+0.002	+0.004	+0.005	+0.005	+0.004

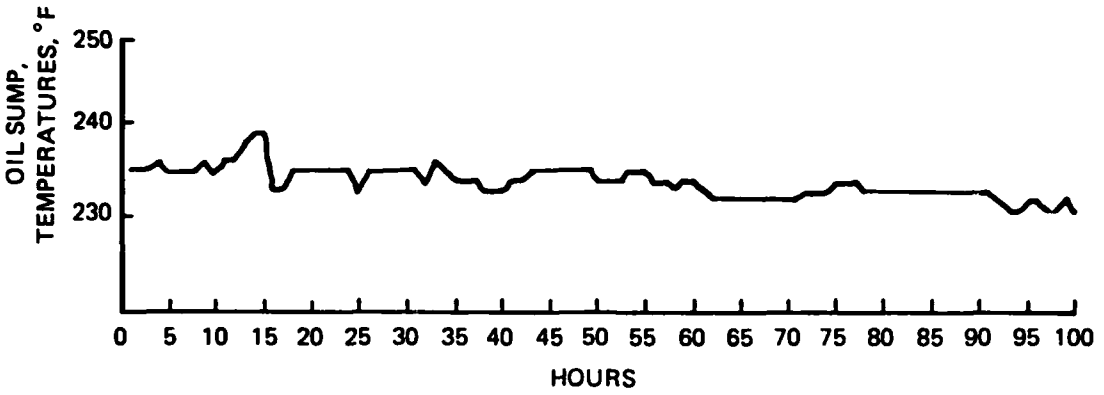
Overall Average Change: +0.003

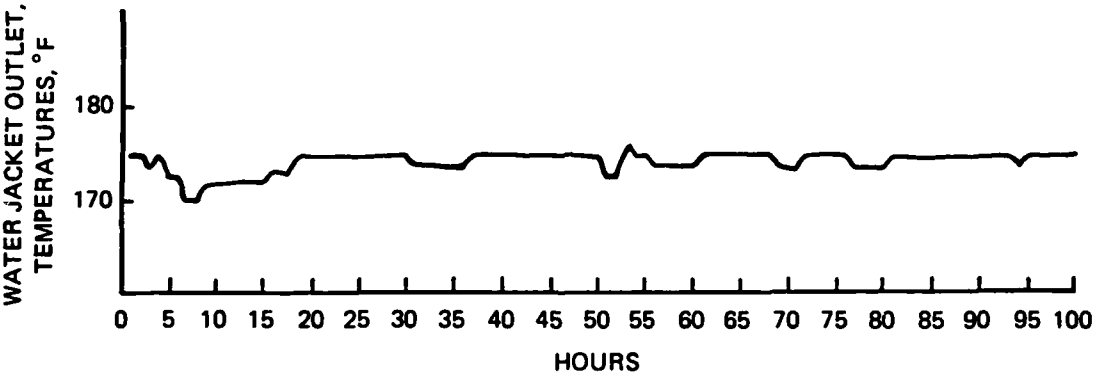
* All dimensions given are in inches.
** T-AT = Thrust - Anti-thrust Direction; F-B = Front - Back Direction.

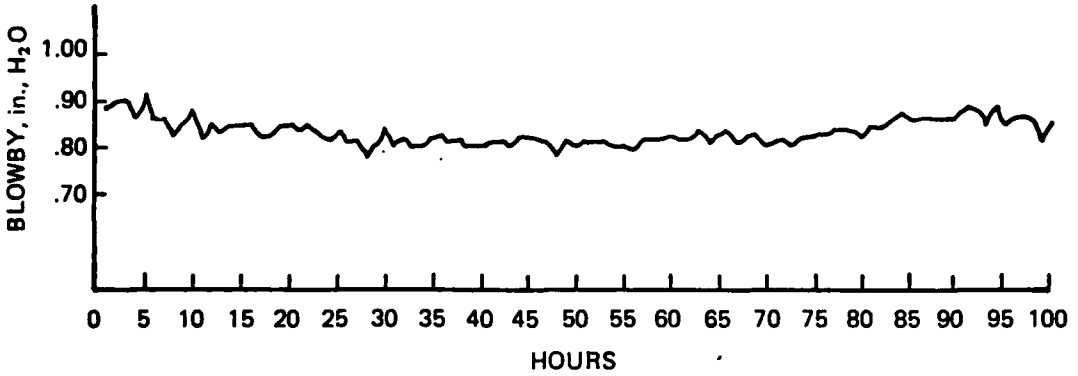

EXHAUST BEFORE TURBO, PRESSURES, psi
13.0
12.0
11.0
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
HOURS

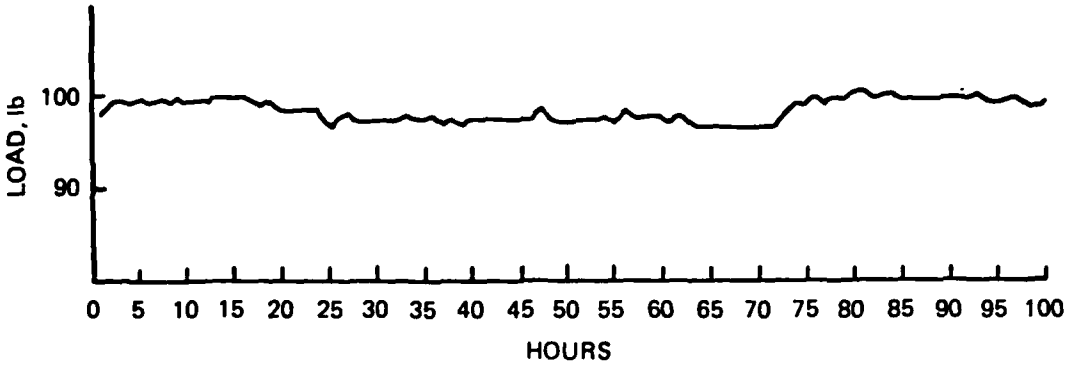

COMPRESSOR DISCHARGE, PRESSURES, psi
10.0
9.0
8.0
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
HOURS

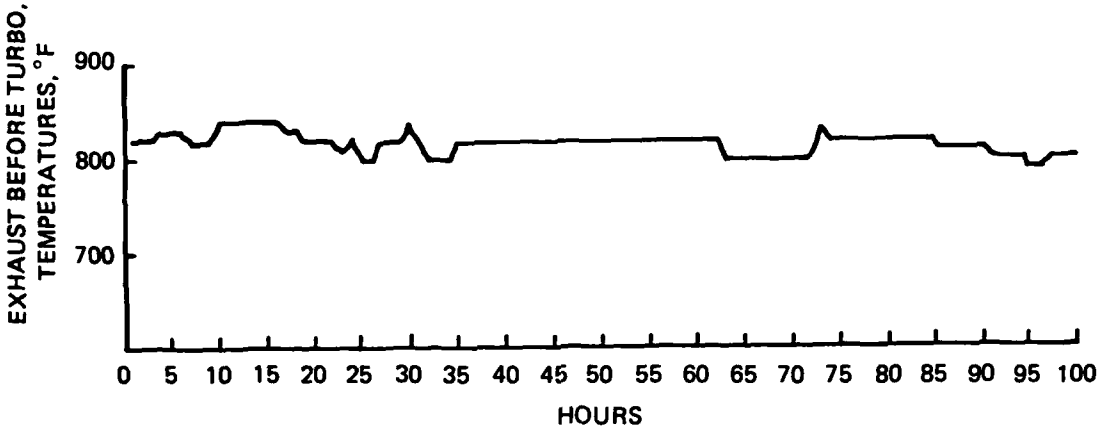

BSFC, lb/bhp-hr
.440
.420
.400
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
HOURS


OIL SUMP, TEMPERATURES, °F
250
240
230
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
HOURS


WATER JACKET OUTLET, TEMPERATURES, °F
180
170
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
HOURS


BLOWBY, in., H_2O
1.00
.90
.80
.70
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
HOURS


LOAD, lb
100
90
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
HOURS


EXHAUST BEFORE TURBO, TEMPERATURES, °F
900
800
700
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
HOURS

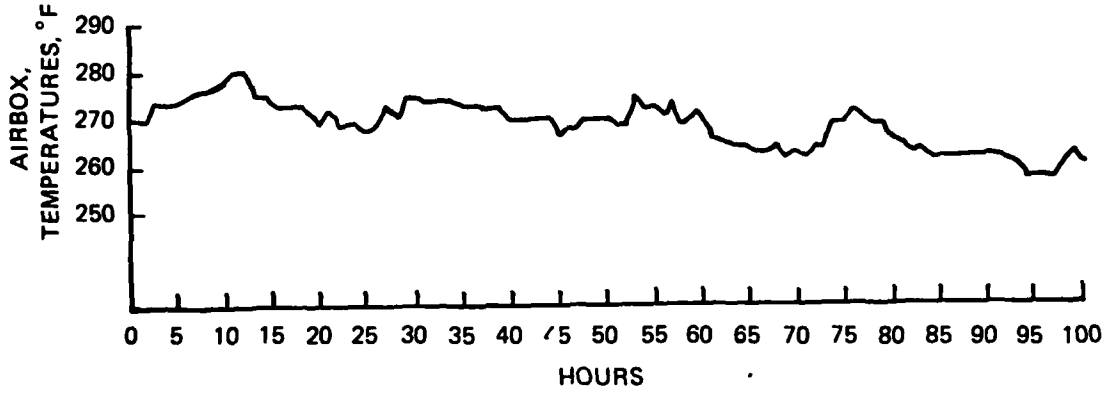
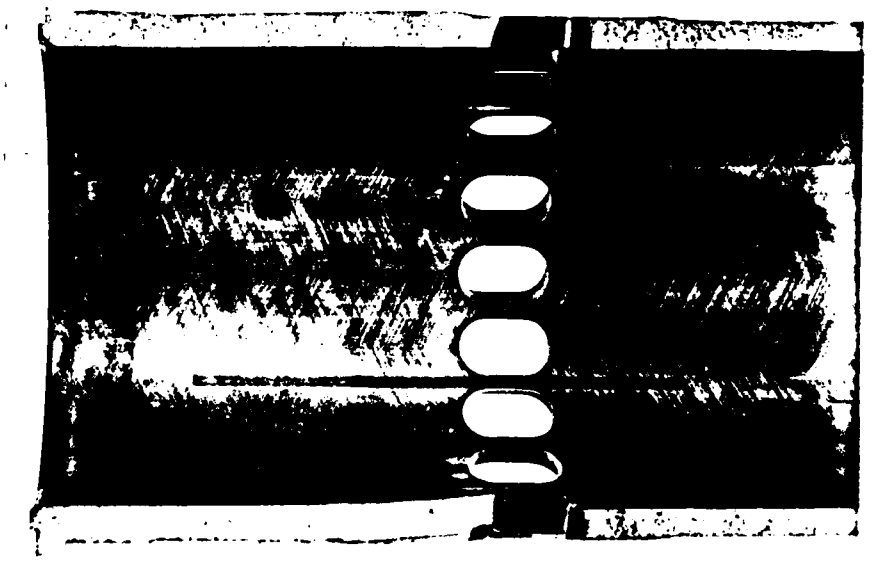

AIRBOX, TEMPERATURES, °F
290
280
270
260
250
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
HOURS

Figure 1. METHOD 354

Condition of Piston and Cylinder Liner

Test Time 100 Hours Test No. MTC-2 Lubricant AL-8925-L

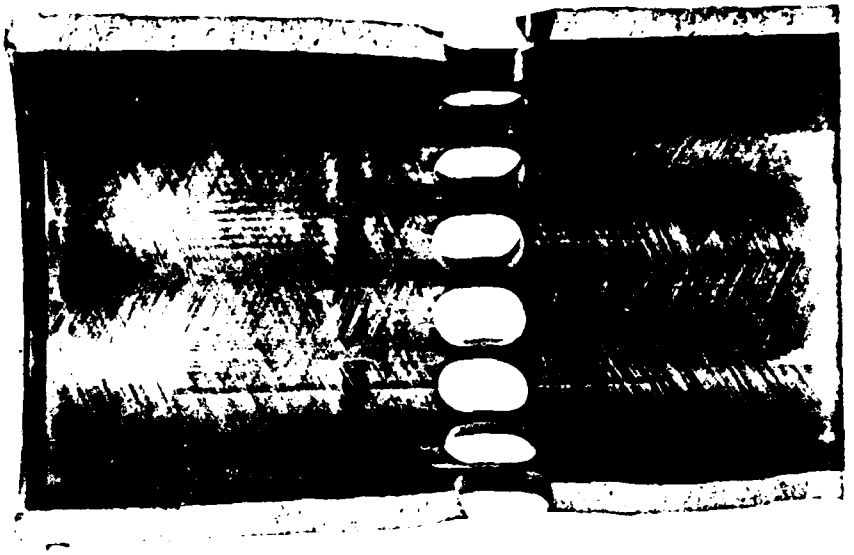


1 Right Thrust

Figure 2. METHOD 354

Condition of Piston and Cylinder Liner

Test Time 100 Hours | Test No. MTC-2 | Lubricant AL-8925-L

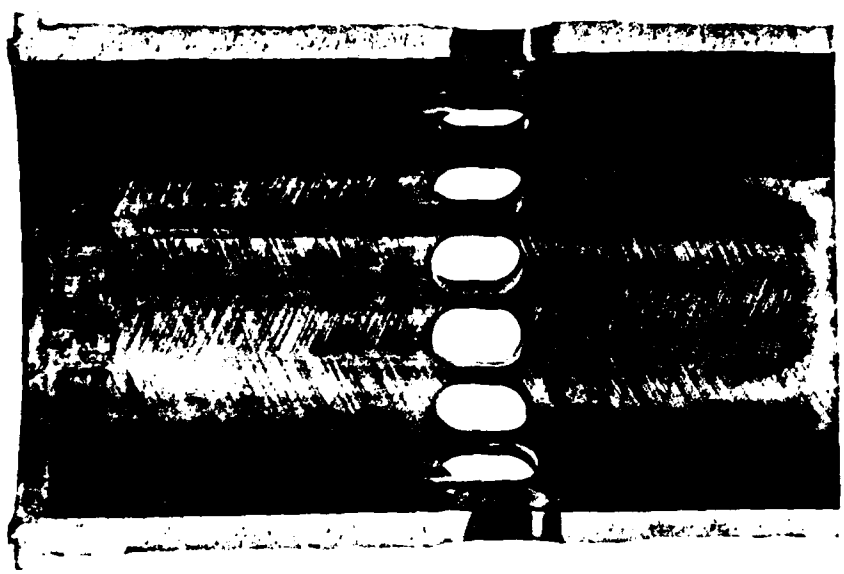


1 Right Anti-Thrust

Fig. 3. Mobil ...

Condition of Piston and Cylinder Liner

Test Time 100 Hours | Test No. MTC-2 | Lubricant AL-8925-L

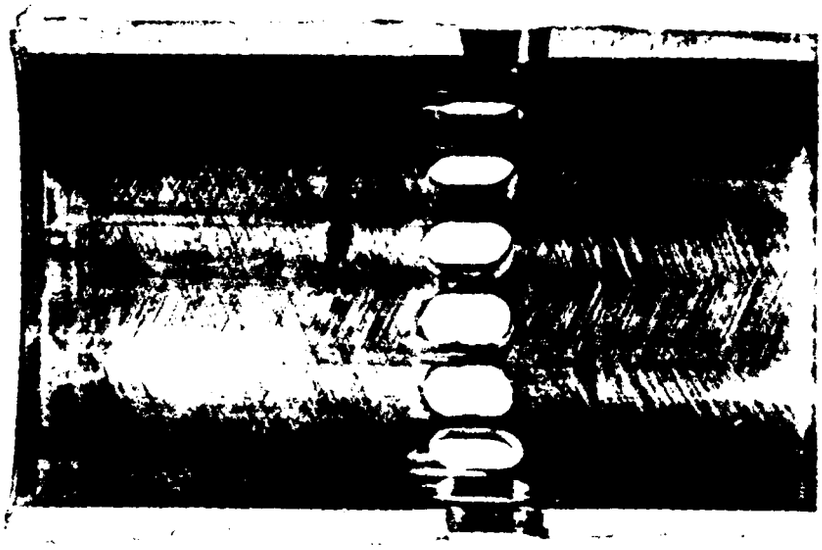


2 Right Thrust

Figure 4. METHOD 3324

Condition of Piston and Cylinder Liner

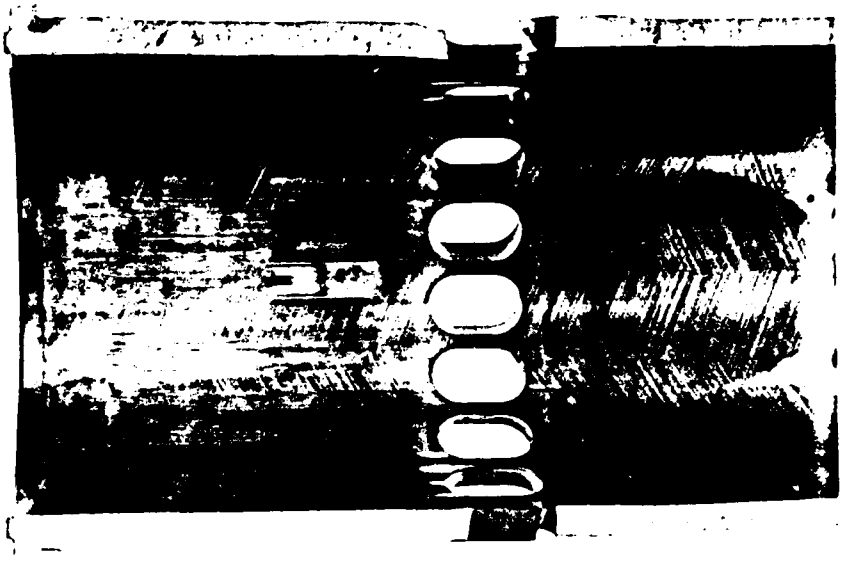
Test Time 100 Hours Test No. MTC-2 Lubricant AL-8925-L



2 Right Anti-Thrust

Condition of Piston and Cylinder Liner

Test Time 100 Hours | Test No. MTC-2 | Lubricant AL-8925-L

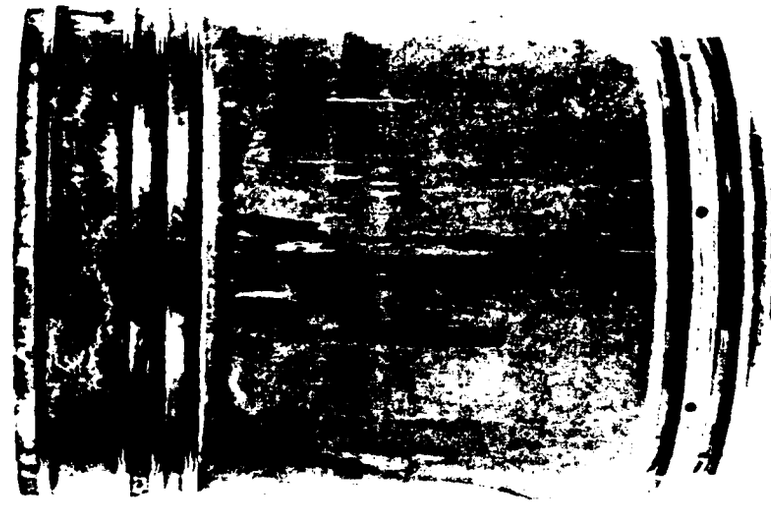


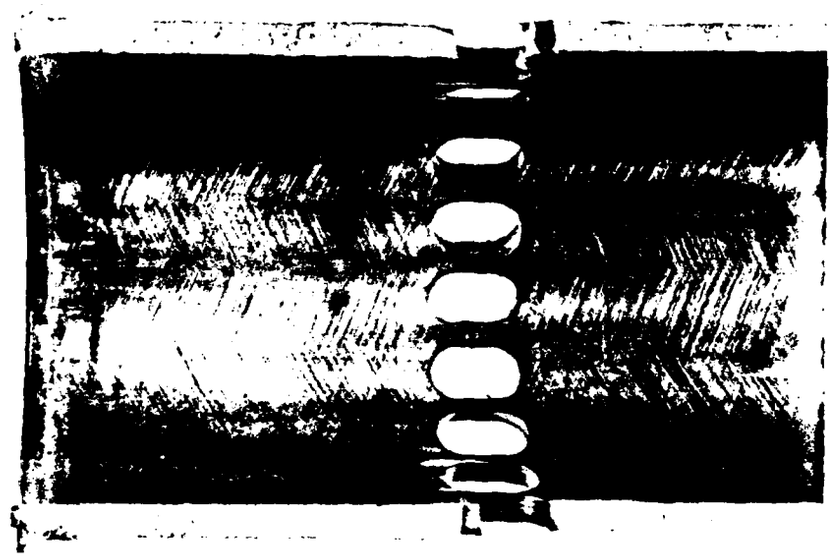
3 Right Thrust

Figure 6. MIL-L-2354

Condition of Piston and Cylinder Liner

Test Time 100 Hours | Test No. MTC-2 | Lubricant AL-8925-L



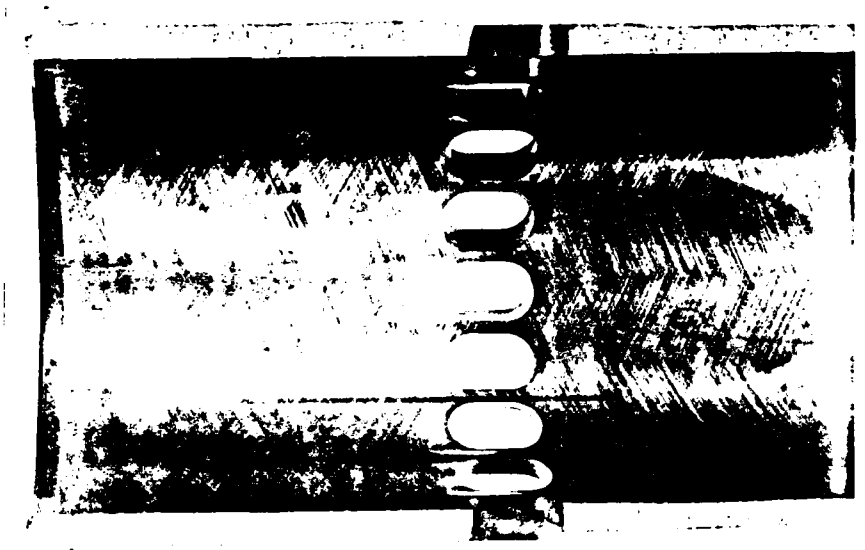


3 Right Anti-Thrust

Figure 7. METHOD 354

Condition of Piston and Cylinder Liner

Test Time 100 Hours Test No. MTC-2 Lubricant AL-8925-L

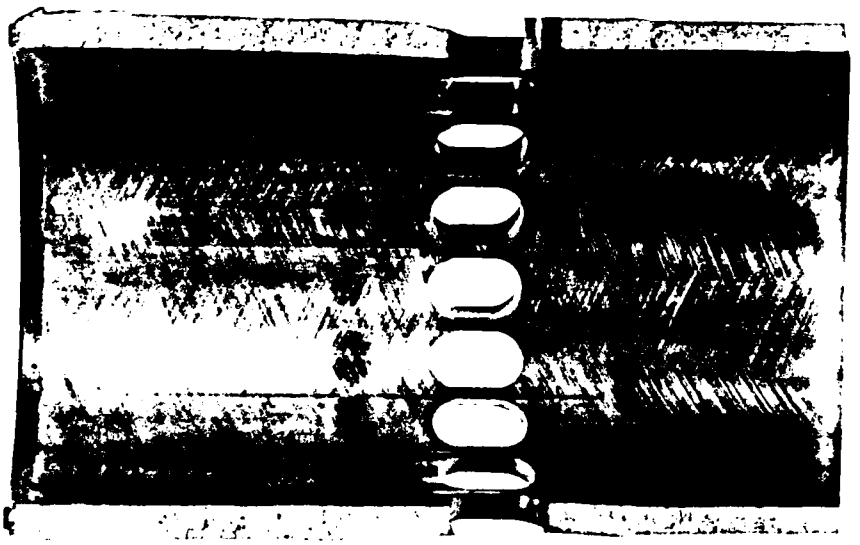


1 - Left Thrust

Figure 8. METHOD 354

Condition of Piston and Cylinder Liner

Test Time 100 Hours | Test No. MTC-2 | Lubricant AL-8925-L

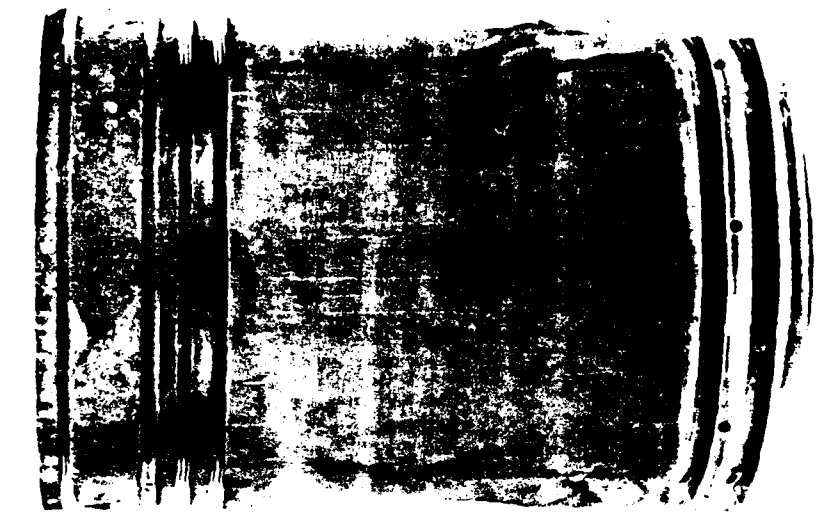


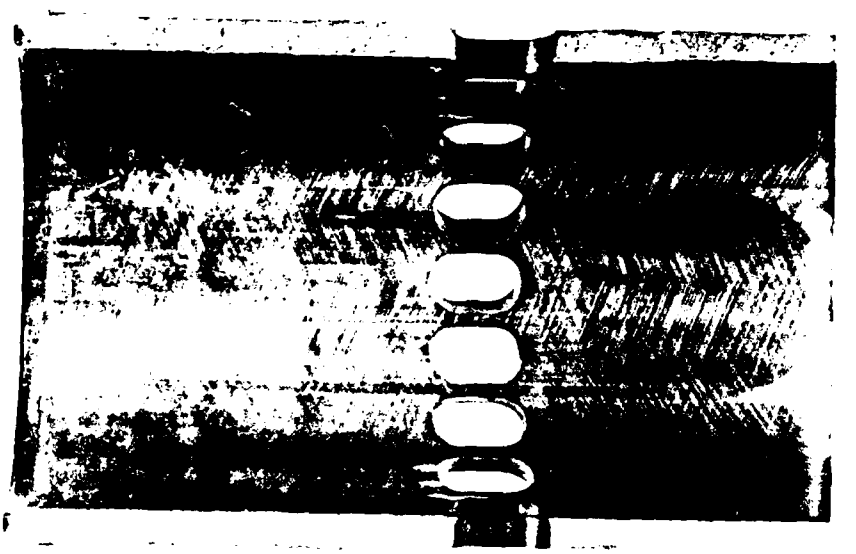
1 Left Anti-Thrust

Figure 9. MIL-HDBK-454

Condition of Piston and Cylinder Liner

Test Time 100 Hours Test No. MTC-2 Lubricant AL-8925-L



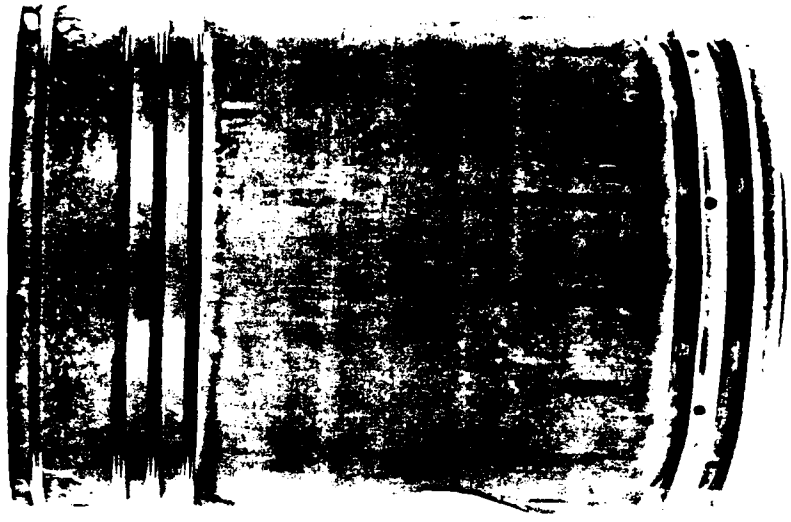


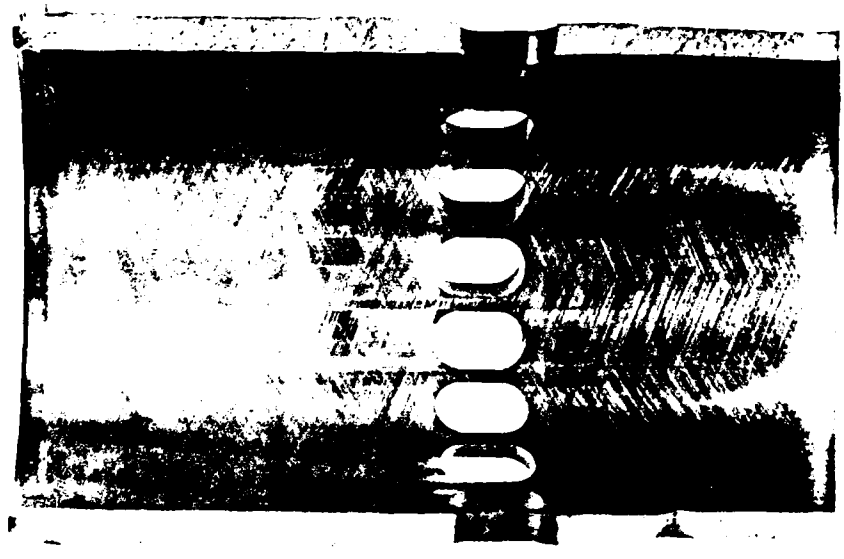
2 Left Thrust

Figure 10. METHOD 364

Condition of Piston and Cylinder Liner

Test Time 100 Hours Test No. MTC-2 Lubricant AL-8925-L



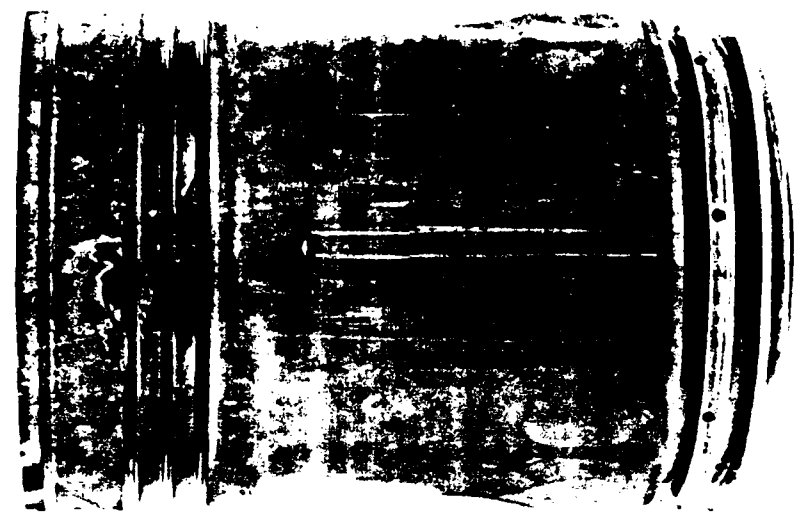


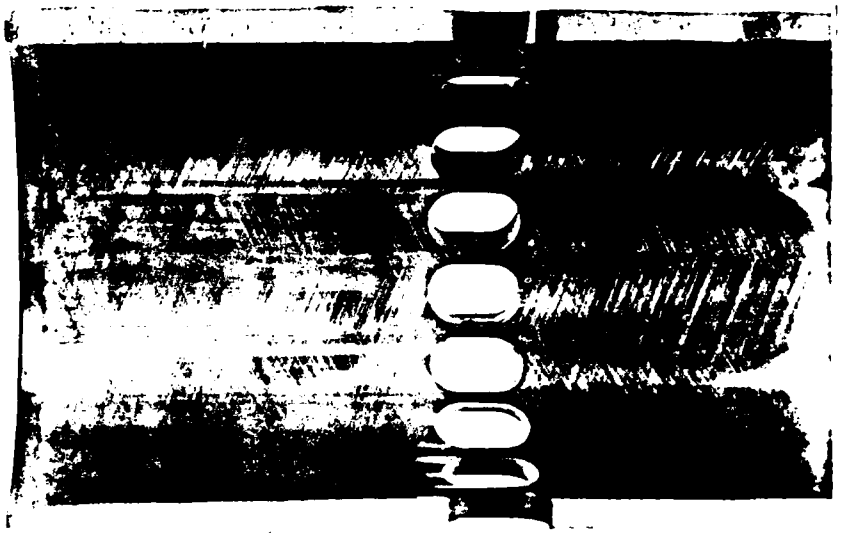
2 Left Anti-Thrust

Figure 11. Mercedes-4

Condition of Piston and Cylinder Liner

Test Time 100 Hours | Test No. MTC-2 | Lubricant AL-8925-L



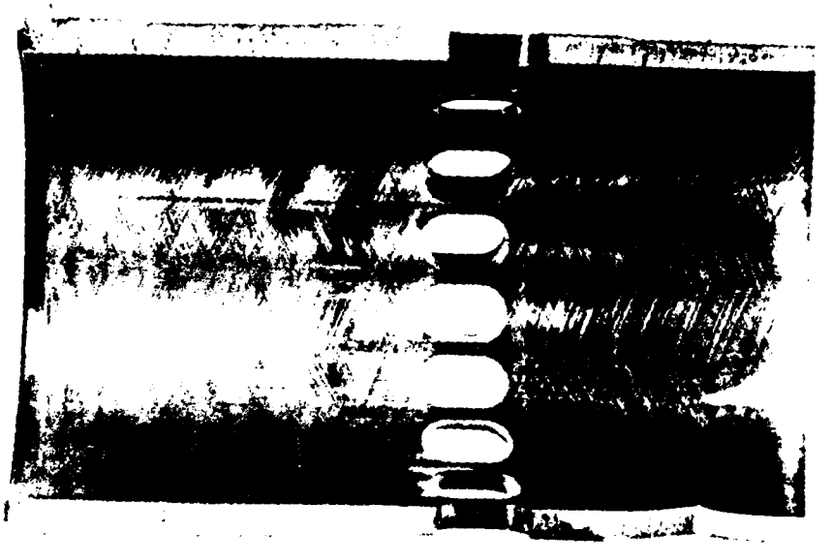


3 Left Thrust

Figure 12. METHOD 354

Condition of Piston and Cylinder Liner

Test Time 100 Hours Test No. MTC-2 Lubricant AL-8925-L

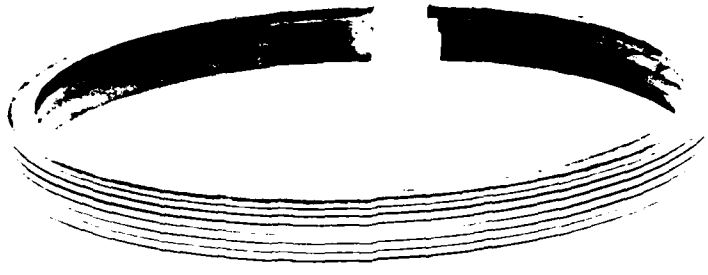


3 Left Anti-Thrust

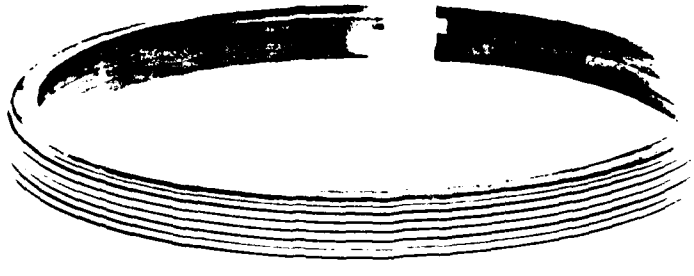
Figure 1. [illegible] 554

Condition of Compression Ring Face

Test Time 100 Hours | Test No. MTC-2 | Lubricant AL-8925-L



1 Right

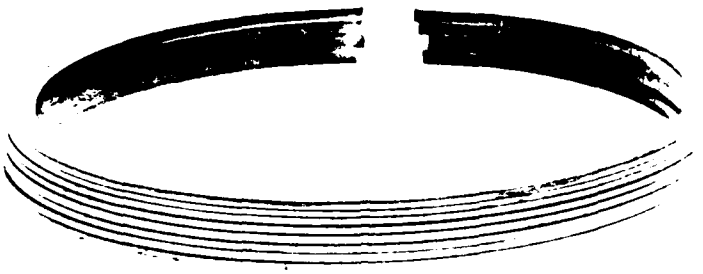


2 Right

Figure 14. METHOD 3054

Condition of Compression Ring Face

Test Time 100 Hours Test No. MTC-2 Lubricant AL-8925-L



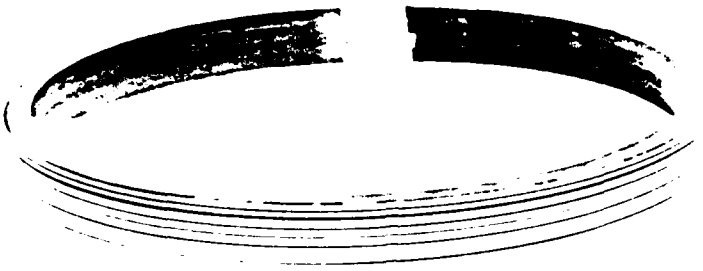
3 Right

1 Left

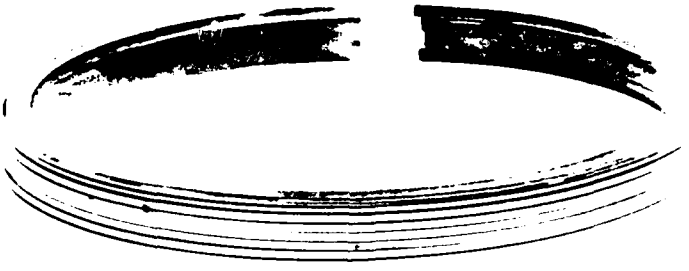
Figure 15. [illegible] 354

Condition of Compression Ring Face

Test Time 100 Hours Test No. MTC-2 Lubricant AL-8925-L



2 Left



3 Left

APPENDIX B

PERFORMANCE OF AL-9841-L LUBRICATING OIL IN A TWO-CYCLE DIESEL ENGINE UNDER STEADY-STATE TURBOSUPERCHARGED CONDITIONS

PERFORMANCE OF AL-9841-L LUBRICATING OIL IN A TWO-CYCLE DIESEL ENGINE UNDER STEADY STATE TURBOSUPERCHARGED CONDITIONS

(Method 354 Fed. Test Method Std. 791B)

Engine Test Number: MTC-3 (Modified Test*)

Date Completed: 10 October 1980

Conducted For

U.S. Army Mobility Equipment Research and Development Command
Energy and Water Resources Laboratory
Fort Belvoir, Virginia

By

U.S. Army Fuels & Lubricants Research Laboratory
Southwest Research Institute
San Antonio, Texas 78284

*Modified Test

This test used the cast iron block version of the DD6V-53T engine. Changes include a cast iron engine block, a 16 plate oil cooler and an 8 plate auxiliary oil cooler.

TABLE 1

6V-53T 6D-151056
BUILD-UP ENGINE MEASUREMENTS

	Measurements*			
	Min.	Max.	Avg.	Specified Limits**
Connecting rod				
Bearing clearance	0.0038	0.0041	0.0040	0.0010 to 0.0040
Cylinder liner block bore				
Taper	0.0001	0.0004	0.0002	0.0015 max.
Out-of-round	0.0001	0.0008	0.0003	0.0015 max.
Inside diameter	4.3567	4.3579	4.3573	4.3565-4.3575 4.3595 max.
Cylinder liners (installed)				
Taper	0.0000	0.0003	0.0002	0.0015 max.
Out-of-round	0.0000	0.0006	0.0002	0.0015 max.
Inside diameter	3.8753	3.8767	3.8759	3.8752-3.8767
Piston to liner fit[1]	0.0078	0.0092	0.0085	0.0060-0.0095
Piston diameter	3.8670	3.8681	3.8675	3.8669-3.8691
Fire ring				
End gap	0.031	0.041	0.036	0.020-0.046
Side clearance	0.003	0.004	0.004	0.003-0.006
#1 Compression ring				
End gap	0.028	0.037	0.033	0.020-0.046
Side clearance	0.008	0.009	0.008	0.007-0.010
#2 & #3 Compression ring				
End gap	0.023	0.038	0.032	0.020-0.046
Side clearance	0.006	0.007	0.007	0.005-0.010
Oil rings				
End gap	0.017	0.023	0.020	0.010-0.025
Side clearance	0.003	0.0035	0.003	0.0015-0.0055

* All measurements given are in inches.
** Wear limits with new liners in a used block.
[1] Thrust-Antithrust direction

TABLE 2

OPERATING DATA SHEET

Test Run at U.S. Army Fuels & Lubricants Research Laboratory (SwRI)

Test Oil: AL-9841-L Test Fuel: 1-H CAT

Test No.: MTC-3 Test Stand: 5 Engine No: 6D-151056

Test Hours: 100 Date Started: 6 October 1980 Completed: 10 October 1980

Total Downtime: 5.42 Hrs Scheduled; 0 Hrs Unscheduled

	Min.	Max.	Avg.
Engine Speed, rpm	2799.	2802.	2800.
Load, lbs	97.	100.	99.
Output, BHp	233.	240.	237.
Fuel Rate, lb/min	1.58	1.63	1.60
Oil Consumption, lb/hr			.8105
Temperature, °F			
Jacket-in	160.	166.	163.
Jacket-out	170.	177.	174.
Oil Sump	230.	237.	233.
Inlet Air (compressor)	75.	96.	87.
Air Box	268.	280.	275.
Exhaust before turbo	820.	870.	851.
Exhaust after turbo	720.	760.	730.
Fuel at filter (secondary)	85.	90.	89.
Pressures			
Compressor suction, in., H_2O	6.60	6.90	6.73
Compressor discharge, psi	9.60	10.30	9.79
Blower discharge, psi	16.50	17.50	17.03
Exhaust before turbo, psi	12.50	13.40	12.96
Exhaust after turbo, in., Hg	1.80	2.40	2.33
Oil gallery, psi	24.00	29.00	28.00
Fuel at filter, psi	56.00	58.00	56.89
Blowby, in., H_2O	1.12	1.71	1.50

TABLE 3

RATING DATA SHEET

Test Run at U.S. Army Fuels & Lubricants Research Laboratory (SwRI)

Test Oil: AL-9841-L Test Fuel: 1-H CAT

Test No.: MTC-3 Test Stand: 5 Engine No: 6D-151056

Test Hours: 100 Date Started: 6 October 1980 Completed: 10 October 1980

A. Cylinder Liner Ratings

Intake Port Plugging

Cylinder No.	Restriction, %
1 L	< 1
2 L	< 1
3 L	< 1
1 R	< 1
2 R	< 1
3 R	< 1
Average	< 1

Scuffing, Glazing, and Lacquer*

Cylinder No.	Scuffing, % Thrust	Scuffing, % Anti-Thrust	Scuffing, % % Total Area	Glazing, %	Lacquer, %
1 L	2	2	2	0	100
2 L	1	1	1	0	100
3 L	75	65	70	0	100
1 R	5+	5	5	0	100
2 R	5+	10	7.5	0	100
3 R	5	5	5	0	100
Average	15.5	14.7	15.1	0	100

* Total Ring Travel Area

\+ Mostly Light Vertical Lines

B. Piston Ratings

Cylinder No.	Ring Sticking and Condition**			
		Ring		
	Fire	No. 1	No. 2	No. 3
1 L	25% c.s.-@ 2	F-0	F-0	F-0
2 L	F-0	F-0	F-0	F-0
3 L	F-#a1	F-a0	F-a5	F-a1
1 R	F-1	F-0	F-0	F-0
2 R	F-1	F-0	F-0	F-0
3 R	F-0	F-0	F-0	F-0

** Numbers denote % area ringface burn
@ Removed
# Partially collapsed
a Heavy wear
F Free

Ring Groove Carbon Filling and Oil Groove Lacquer

Cylinder No.	Groove Filling, %				Oil Groove Lacquer (Demerit)	
	Fire	No. 1	No. 2	No. 3	Upper	Lower
1 L	5	0	0	0	3.0	3.0
2 L	5	15	0	0	3.0	3.0
3 L	10	55	5	1	3.0	3.0
1 R	5	5	0	0	3.0	3.0
2 R	5	20	0	0	3.0	3.0
3 R	5	3	0	0	3.0	3.0

Land Description

Cylinder No.	Description
1 L	Normal
2 L	Normal
3 L	Normal
1 R	Normal
2 R	Normal
3 R	Normal

Skirt (Demerit)

Cylinder No.	Thrust	Anti-Thrust
1 L	5.5 Lt. Sct	5.9 Lt. Sct
2 L	6.0 Lt. Sct	5.9 Lt. Sct
3 L	5.6 Lt. Sct, 15% P. Melt	6.0 Lt. Sct, Scuffing, 25% P. Melt
1 R	5.0 Lt. Sct	4.5 Lt. Sct
2 R	5.9 Lt. Sct	5.5 Lt. Sct
3 R	5.5 Lt. Sct	5.3 Lt. Sct

C. Other Ratings

Combustion Chambers with Exhaust Valves, %

Cylinder No.	Description
1 L	20B-70A-10½A
2 L	25B-70A-5½A
3 L	15B-70A-15½A
1 R	15B-65A-20½A
2 R	5B-75A-20½A
3 R	5C-5B-85A-5½A

D. Interim Inspections

Zero Test Hours	Inspection	Zero Test Hours	Inspection
1 L	Normal	1 R	Normal
2 L	Normal	2 R	Normal
3 L	Normal	3 R	Normal

24 Test Hours	Inspection	24 Test Hours	Inspection
1 L	Normal	1 R	Normal
2 L	Normal	2 R	Normal
3 L	Cylinder Liner-Med. to Hvy. Scuffing	3 R	Normal

48 Test Hours	Inspection	48 Test Hours	Inspection
1 L	Normal	1 R	Normal
2 L	Cylinder Liner, Med. to Hvy. Glazing	2 R	Normal
3 L	Cylinder liner, Hvy Scuffing & Glazing	3 R	Normal

72 Test Hours	Inspection	72 Test Hours	Inspection
1 L	Normal	1 R	Cylinder Liner, Med. to Hvy Glazing
2 L	Cylinder Liner, Med. to Hvy. Glazing	2 R	Normal
3 L	Piston Skirt, Lt. P. Melt on AT-side; Cylinder liner, AT-side, Hvy. Scuffing	3 R	Normal

TABLE 3 - Continued

E. Legend

Abbreviations	Definitions
T-Side	Thrust side of cylinder liner or piston skirt. (Inboard left bank and outboard right bank)
AT-Side	Anti-thrust side of cylinder liner or piston skirt. (Side opposite thrust side).
Lt	Light
Med.	Medium
Hvy.	Heavy
P. Melt	Melting of the plating on the piston's surface
Sct	Scratching
Frt	Front of piston or liner
Rt	Rear of piston or liner
Normal	All components considered normal, unless specified otherwise. This means rings are free, only light scuffing of liner and piston skirts, hard carbon on fire lands and lacquer on other ring lands.
c.s.	Cold Stuck

TABLE 4

OIL ANALYSES DATA SHEET

Test Run at U.S. Army Fuels & Lubricants Research Laboratory (SwRI)

Test Oil - AL-9841-L Test Fuel 1-H CAT

Test No. MTC-3 Test Stand 5 Engine No. 6D-151056

Test Hours 100 Date: Started 6 October 1980 Completed: 10 October 1980

Determination	New Oil	Test Hour Sample							
		12	24	36	48	60	72	84	100
Viscosity, cSt									
at 40°C			32.92		33.96		34.17		34.89
at 100°C			6.28		6.41		6.62		6.57
Total Acid Number	3.11		3.36		4.35		4.35		4.60
Total Base Number	5.30		3.83		3.71		3.86		3.90
Sulfated Ash, %			1.14		1.23				1.33
Flash Point, °C			222.		220.				224.
Iron Content, ppm			165.	527.	455.	341.	299.	182.	236.
Carbon Residue, %			1.35		1.54		1.55		1.62

TABLE 5

Lubricant: AL-9841-L

WEAR MEASUREMENTS

Cylinder Liner Bore Diameter Change*

Cylinder Number

	1L		2L		3L	
	T-AT**	F-B**	T-AT	F-B	T-AT	F-B
Top	+0.0009	-0.0003	+0.0004	+0.0001	+0.0069	+0.0034
Middle	+0.0008	-0.0001	+0.0004	-0.0001	+0.0043	+0.0046
Bottom	0.0000	+0.0001	+0.0001	+0.0003	+0.0001	+0.0004

Cylinder Number

	1R		2R		3R	
	T-AT	F-B	T-AT	F-B	T-AT	F-B
Top	+0.0006	+0.0002	+0.0007	0.0000	+0.0009	-0.0001
Middle	+0.0003	+0.0001	+0.0005	+0.0001	+0.0005	+0.0002
Bottom	+0.0002	+0.0002	+0.0002	+0.0002	+0.0002	+0.0001

Average Change

	T-AT	F-B
Top	+0.0173	+0.0006
Middle	+0.0011	+0.0008
Bottom	+0.0001	+0.0002

Overall Average Change: +0.0008

Piston Ring End Gap Change

Ring Number	1L	2L	3L	1R	2R	3R	Average Change
1	+.002	+.002	+.011	+.002	+.004	+.004	+0.004
2	+.001	+.001	+.009	+.002	+.003	+.002	+0.003
3	+.002	+.002	+.004	+.002	+.001	+.002	+0.002
4	+.001	+.001	+.006	+.002	+.002	+.003	+0.003
5	+.007	+.010	+.147	+.007	+.007	+.009	+0.031
6	+.006	+.006	+.099	+.006	+.007	+.008	+0.022
7	+.006	+.007	+.113	+.006	+.006	+.004	+0.024

Overall Average Change: +0.013

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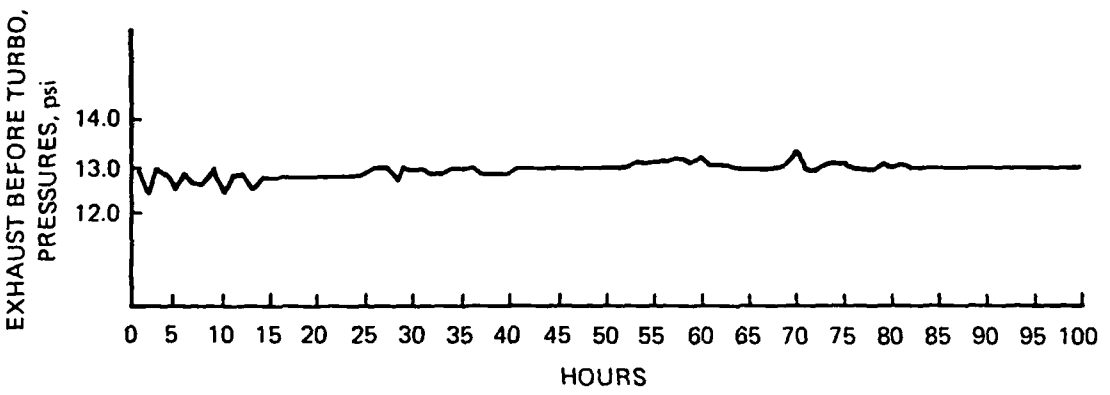
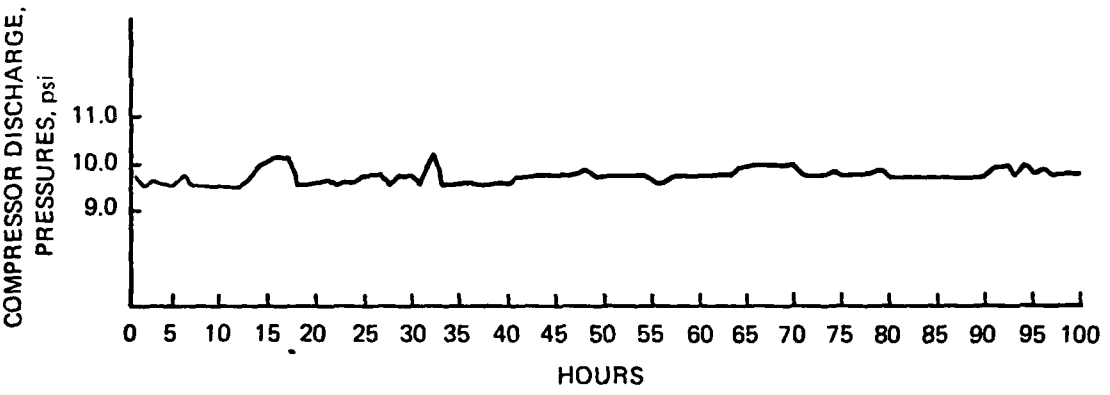
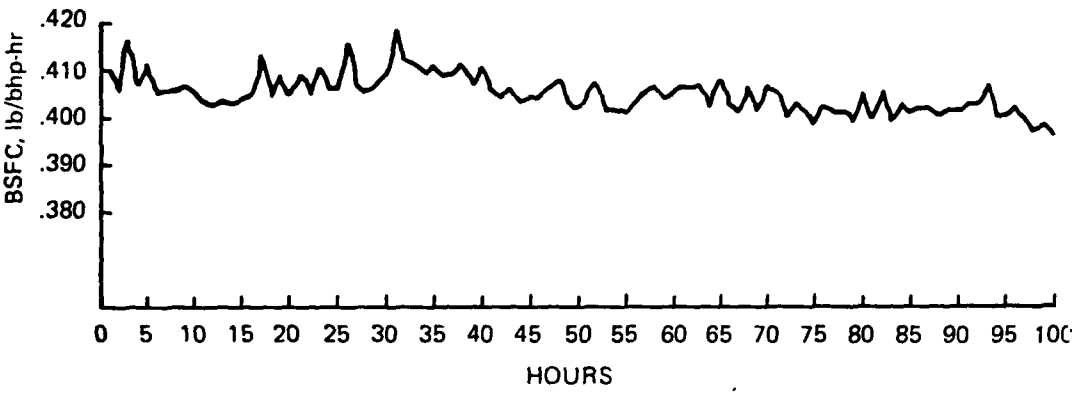
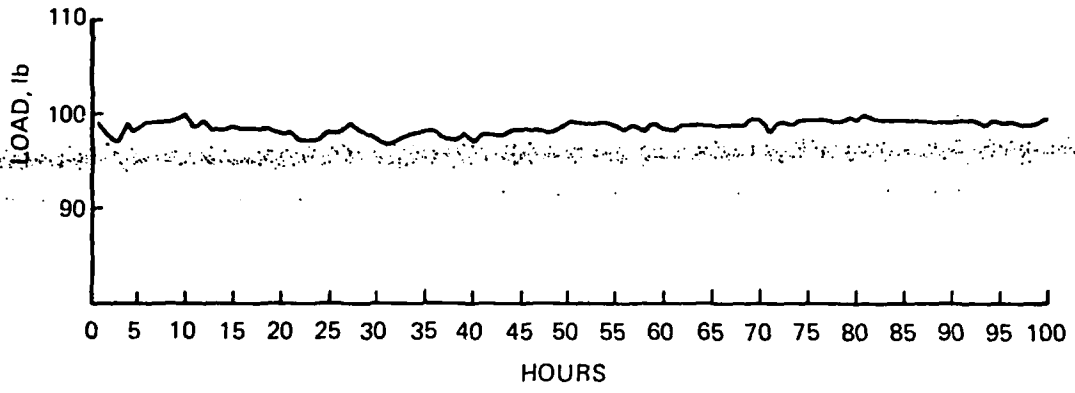
* All measurements given are in inches

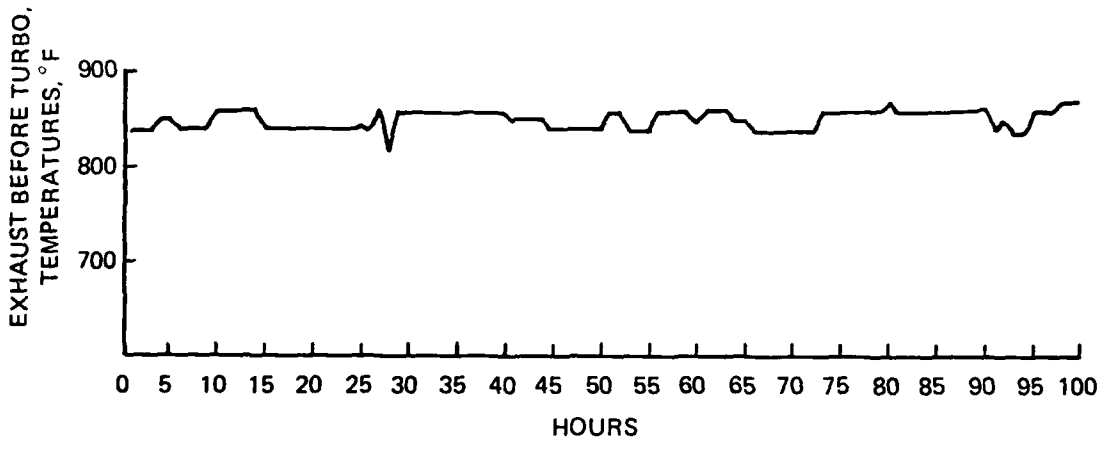
** T-AT = Thrust - Anti-thrust Direction; F-B = Front - Back Direction

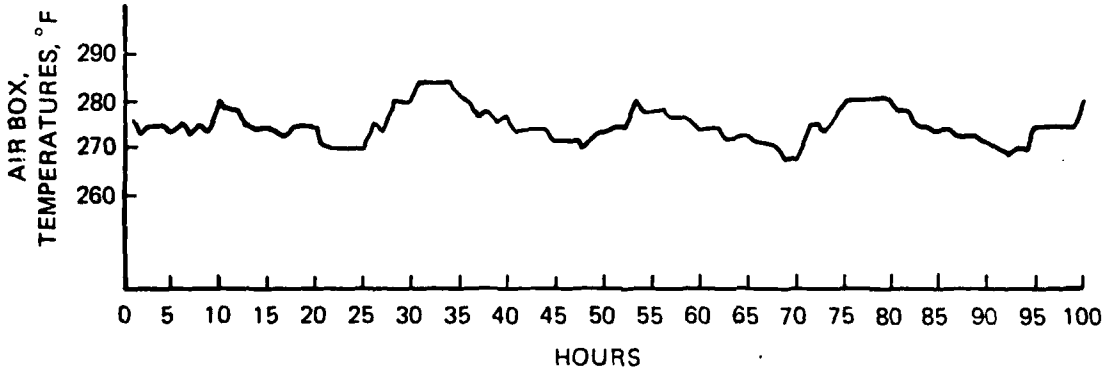

EXHAUST BEFORE TURBO, PRESSURES, psi
14.0
13.0
12.0
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
HOURS

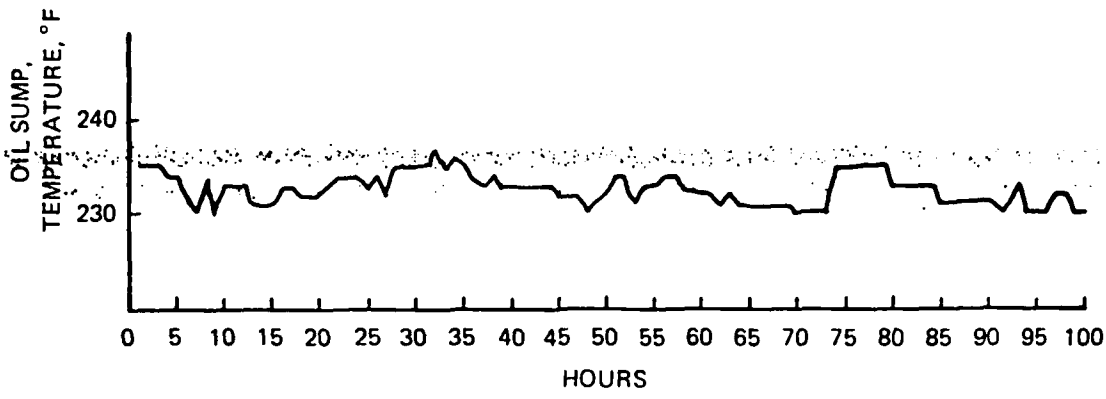

COMPRESSOR DISCHARGE, PRESSURES, psi
11.0
10.0
9.0
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
HOURS

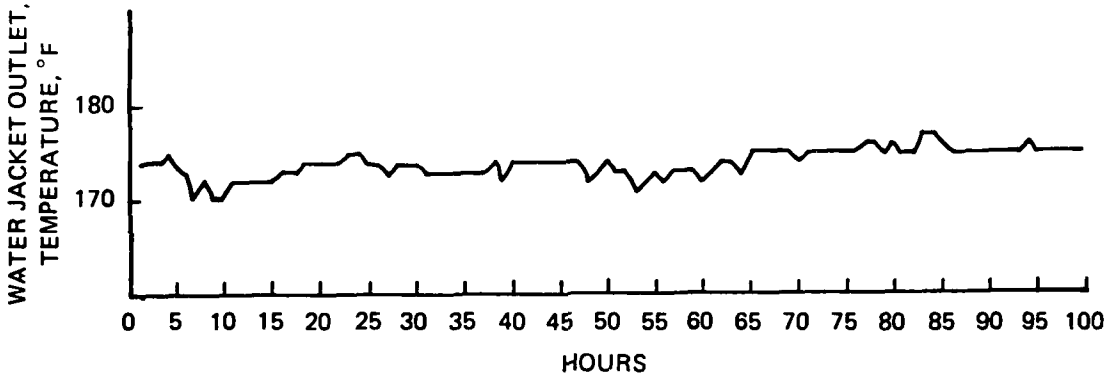

BSFC, lb/bhp-hr
.420
.410
.400
.390
.380
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
HOURS


LOAD, lb
110
100
90
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
HOURS


EXHAUST BEFORE TURBO, TEMPERATURES, °F
900
800
700
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
HOURS


AIR BOX, TEMPERATURES, °F
290
280
270
260
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
HOURS


OIL SUMP, TEMPERATURE, °F
240
230
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
HOURS


WATER JACKET OUTLET, TEMPERATURE, °F
180
170
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
HOURS

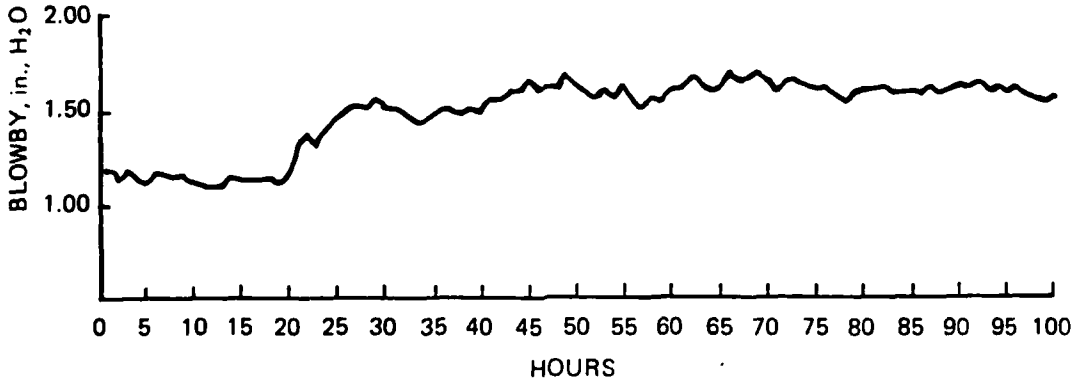
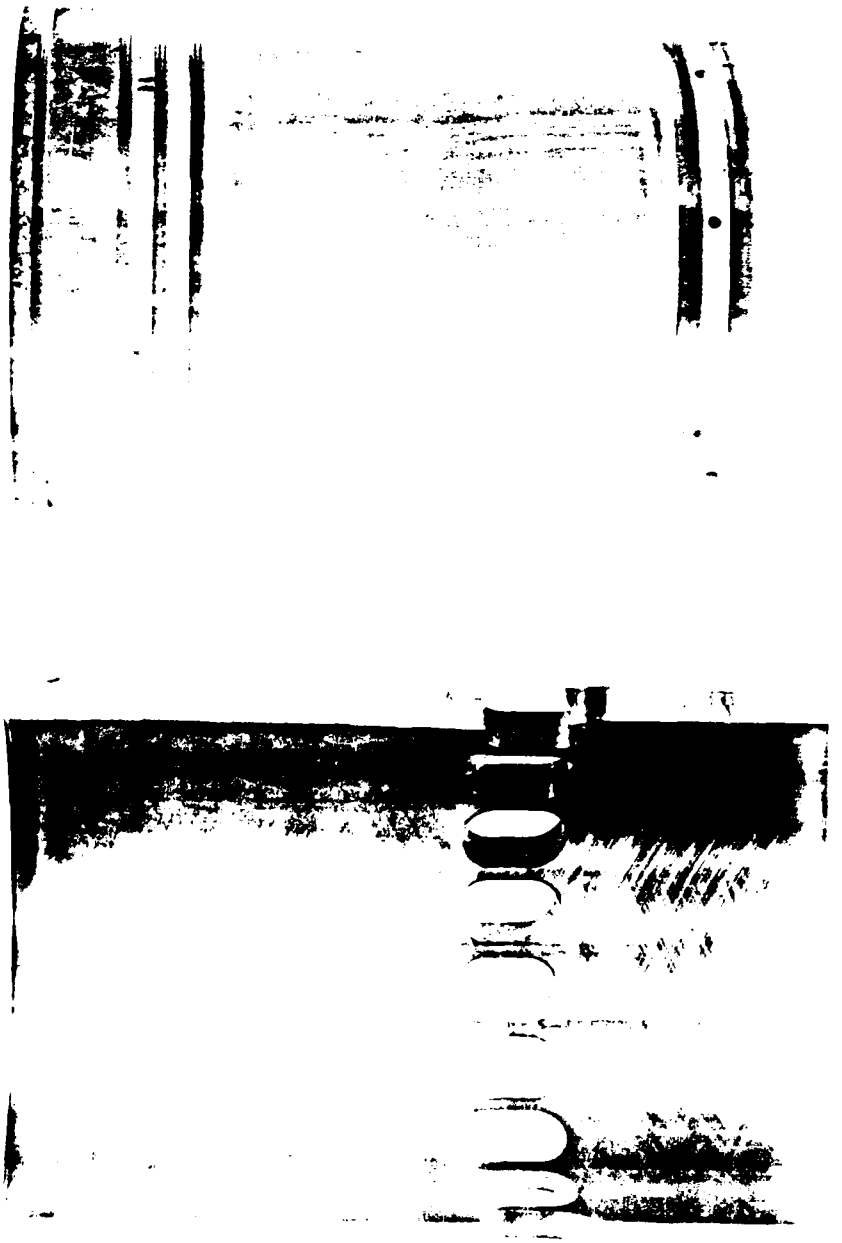

BLOWBY, in., H_2O
2.00
1.50
1.00
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
HOURS

Figure 1. METHOD 354

Condition of Piston and Cylinder Liner

Test Time 100 Hours Test No. MTC-3 Lubricant No. AL-9841-L

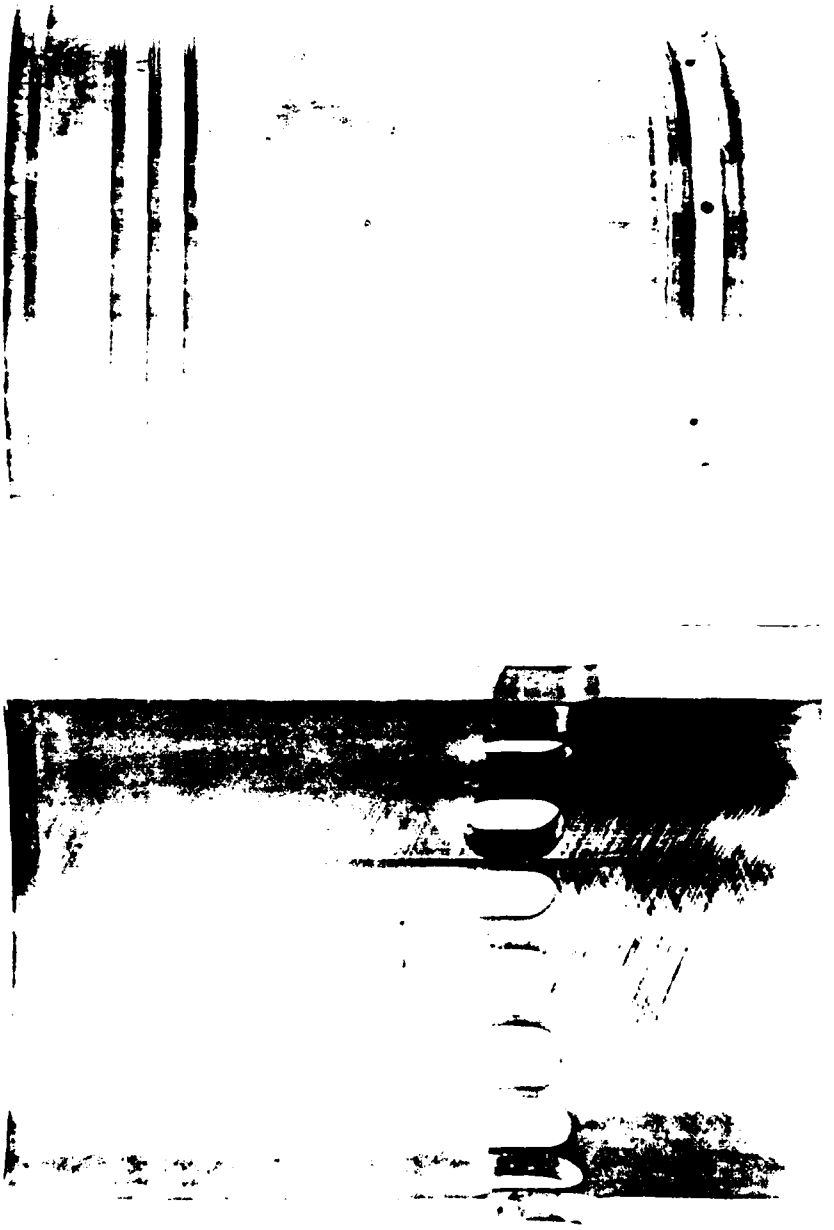


1 Right Thrust

Figure 2. METHOD 354

Condition of Piston and Cylinder Liner

Test Time 100 Hours Test No. MTC-3 Lubricant No. AL-9841-L

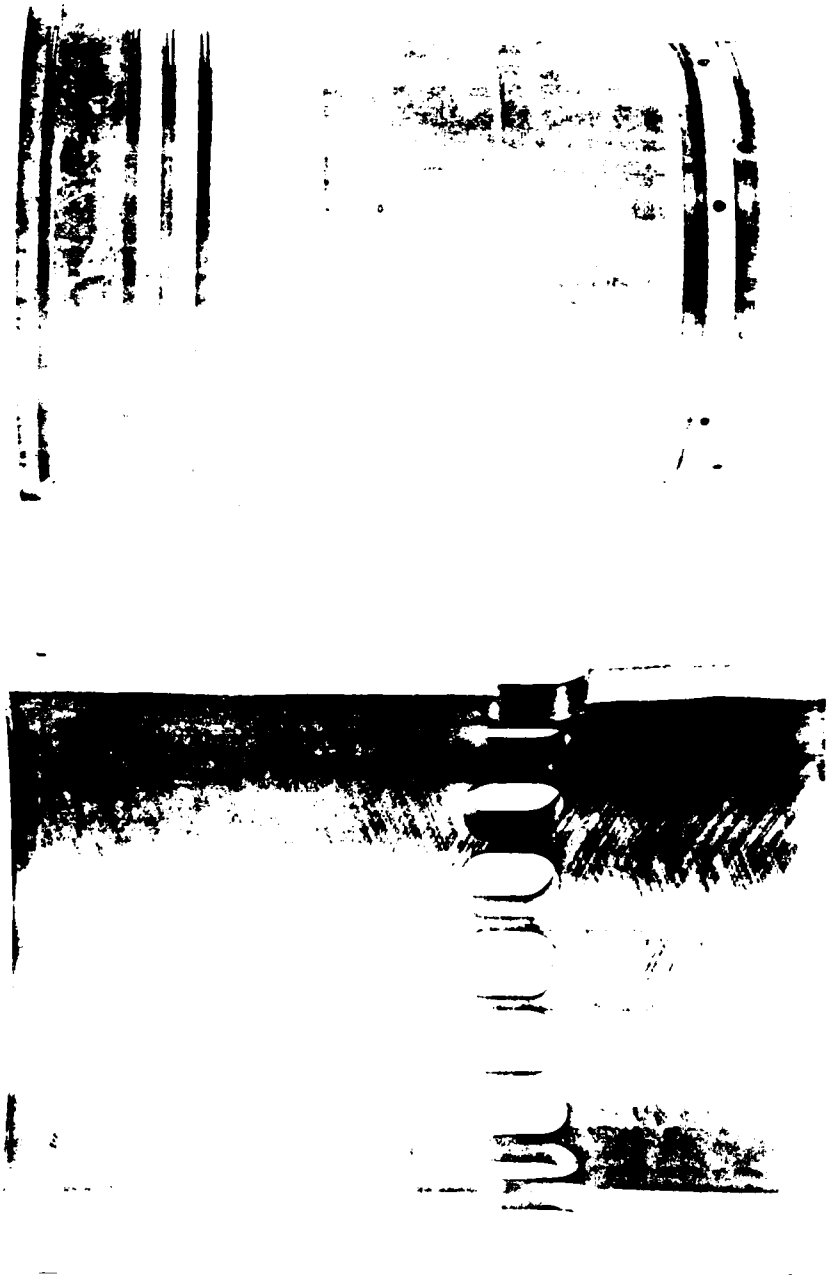


1 Right Antithrust

Figure 3. METHOD 354

Condition of Piston and Cylinder Liner

Test Time 100 Hours Test No. MTC-3 Lubricant No. A1-9841-L

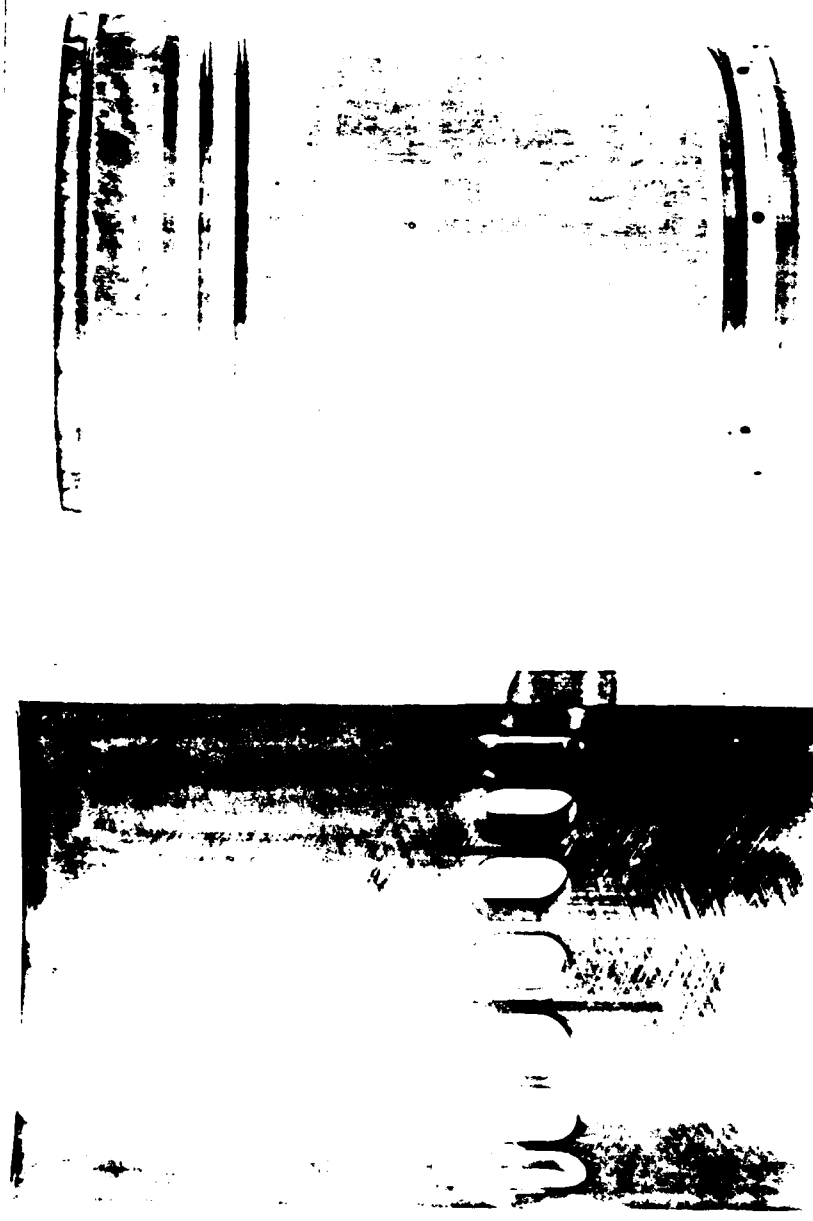


2 Right Antithrust

Figure 4. METHOD 354

Condition of Piston and Cylinder Liner

Test Time 100 Hours Test No. MTC-3 Lubricant No. AL-9841-L

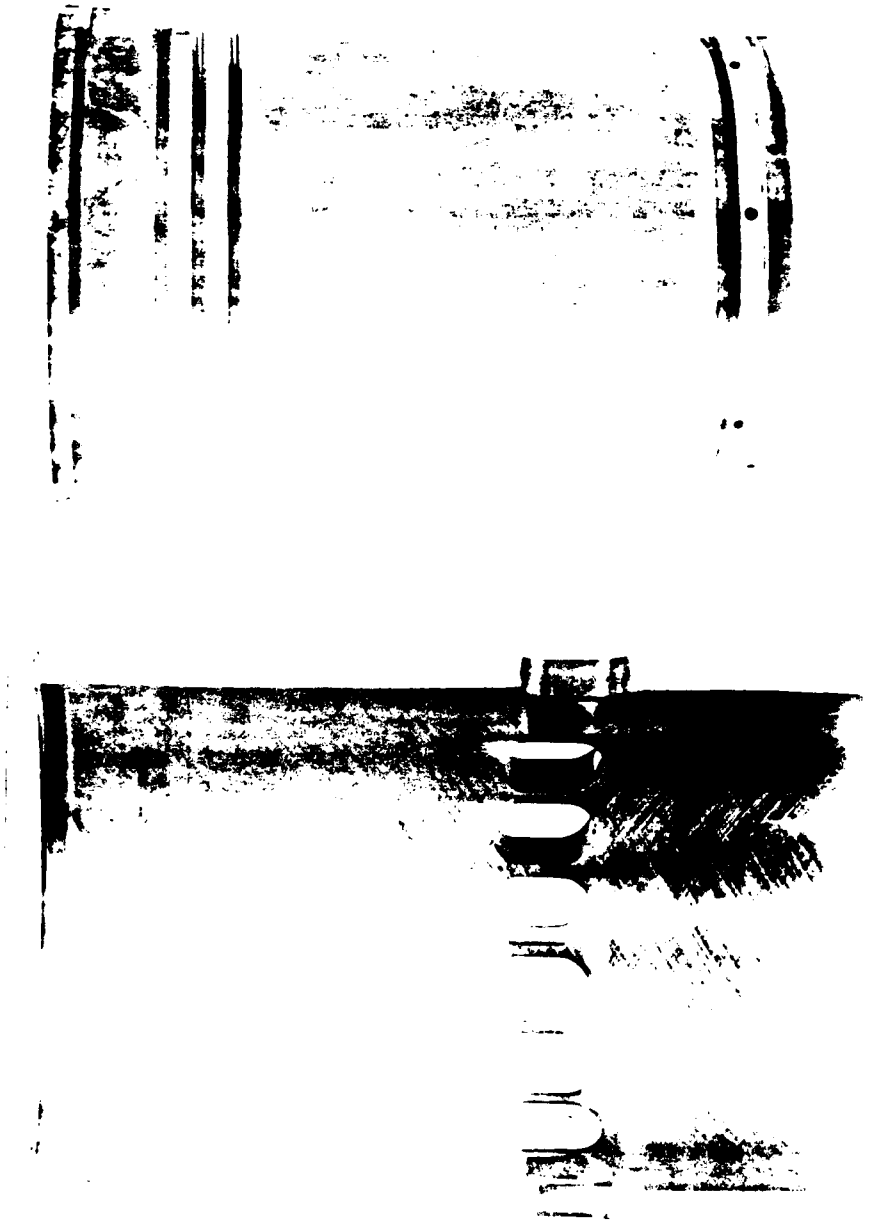


2 Right Antithrust

Figure 5. METHOD 354

Condition of Piston and Cylinder Liner

Test Time 100 Hours Test No. MTC-3 Lubricant No. AL-9841-L

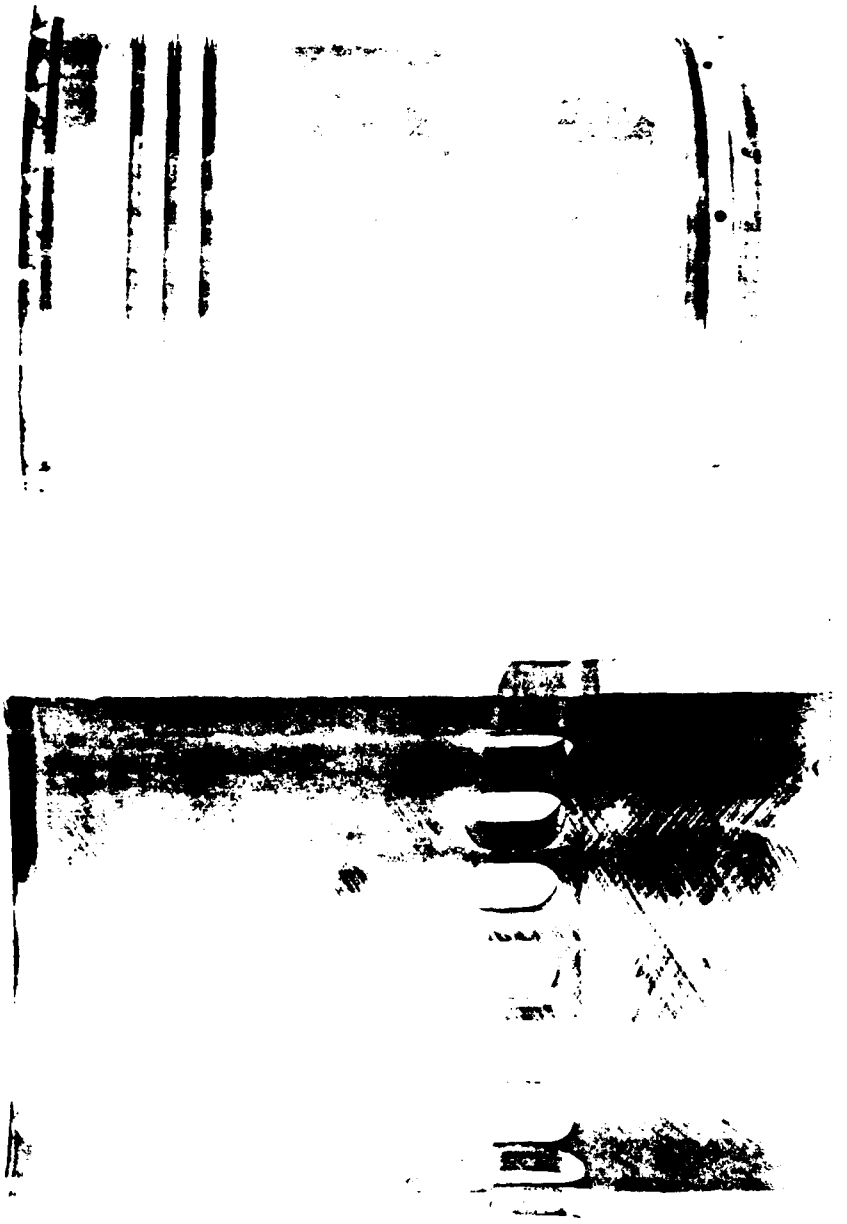


3 Right Thrust

Figure 6. METHOD 354

Condition of Piston and Cylinder Liner

Test Time 100 Hours Test No. MTC-3 Lubricant No. AL-9841-L

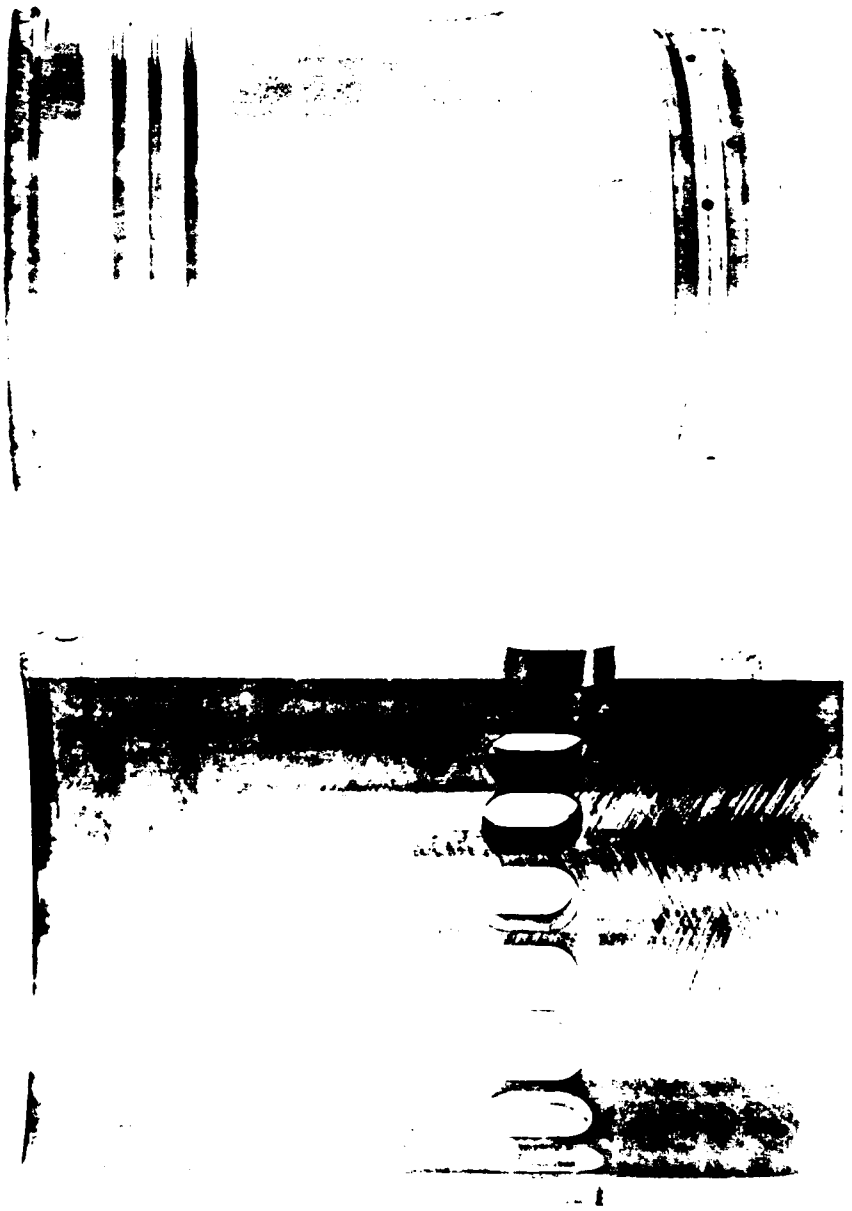


3 Right Antithrust

Figure 7. METHOD 354

Condition of Piston and Cylinder liner

Test Time 100 Hours Test No. MTC-3 Lubricant No. AL-9841-L

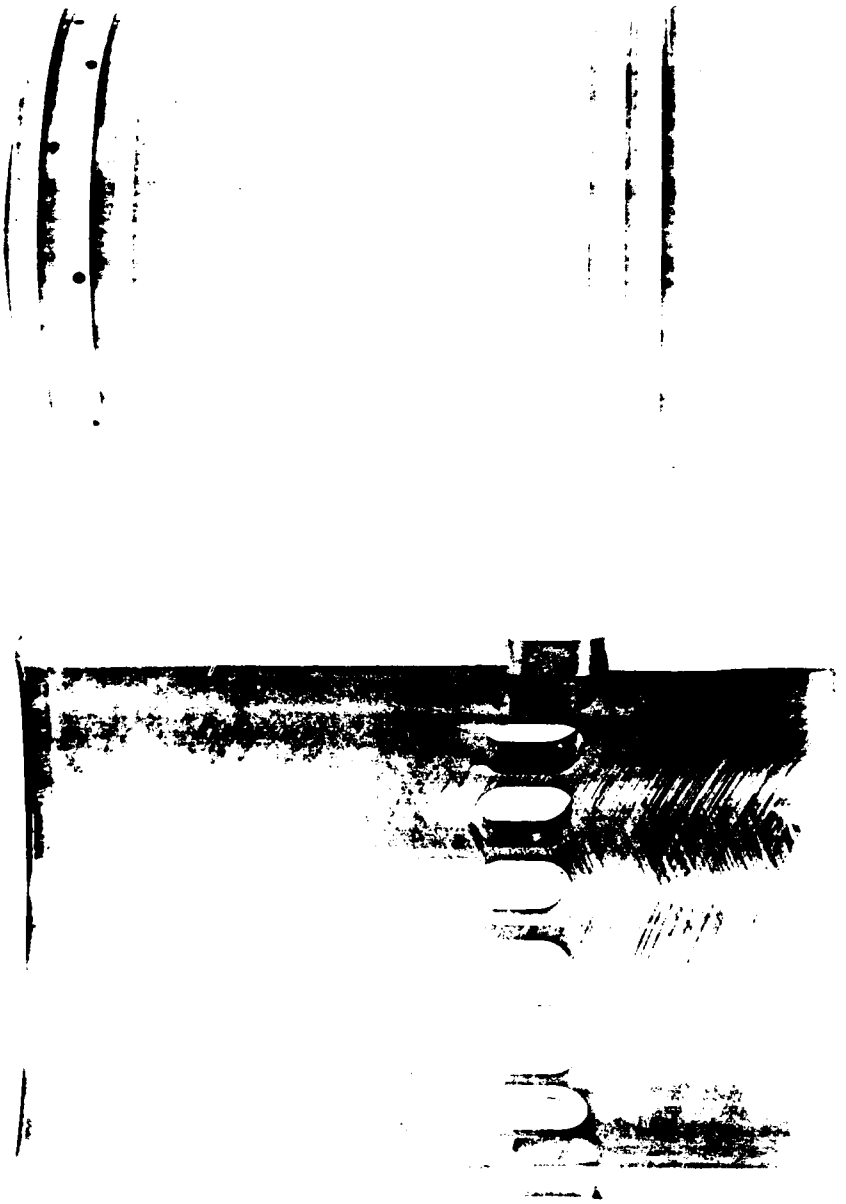


1 Left Thrust

Figure 8. METHOD 354

Condition of Piston and Cylinder liner

Test Time 100 Hours Test No. MTC-3 Lubricant No. AL-9841-L

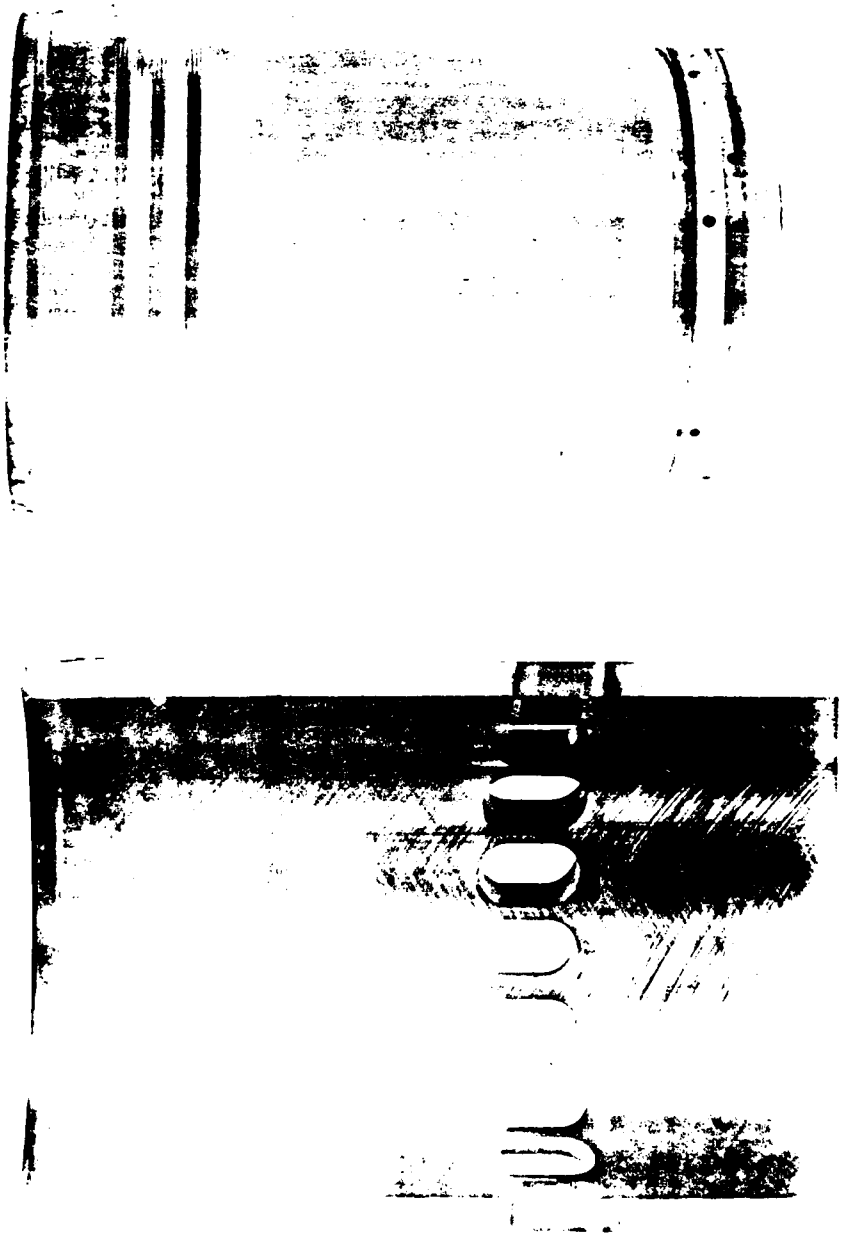


1 Left Antithrust

Figure 9. METHOD 354

Condition of Piston and Cylinder liner

Test Time 100 Hours Test No. MTC-3 Lubricant No. AL-9841-L

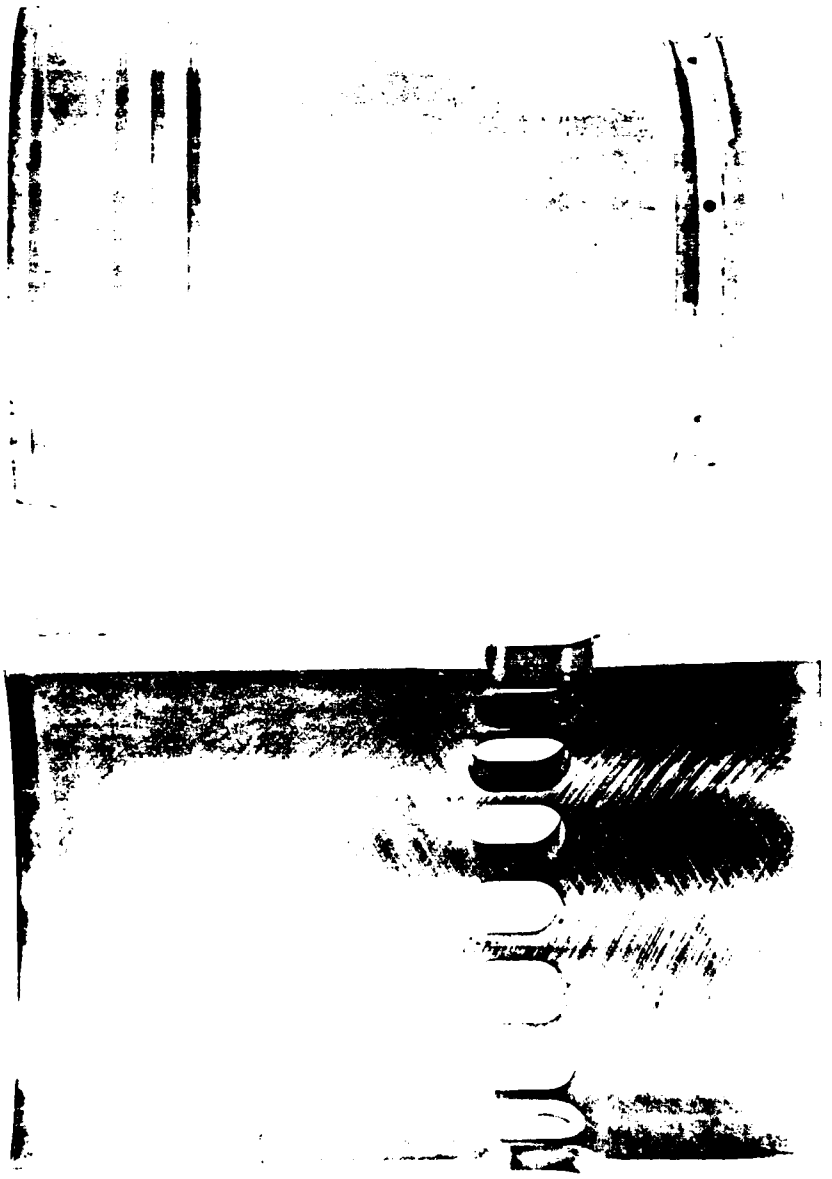


2 Left Thrust

Figure 10. METHOD 354

Condition of Piston and Cylinder Liner

Test Time 100 Hours Test No. MTC-3 Lubricant No. AL-9841-L

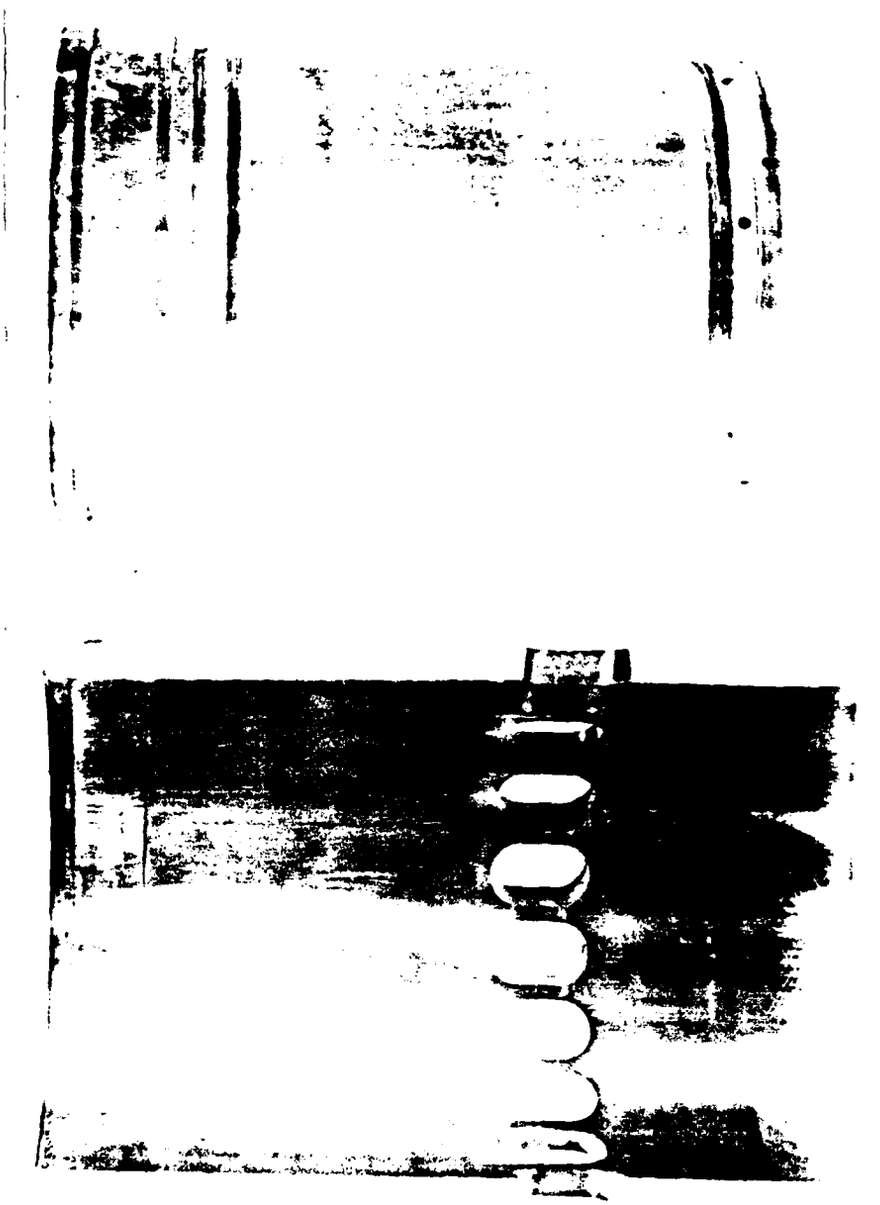


2 Left Antithrust

Figure 11. METHOD 354

Condition of Piston and Cylinder Liner

Test Time 100 Hours Test No. MTC-3 Lubricant No. AL-9841-L



3 Left Thrust

Figure 12. METHOD 354

Condition of Piston and Cylinder Liner

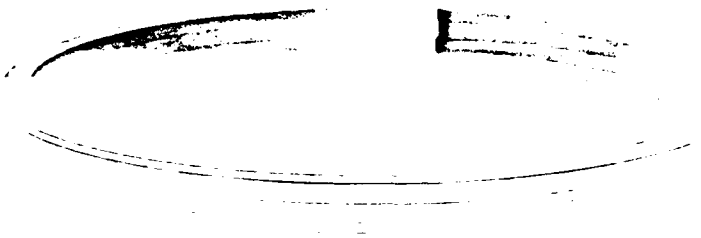
Test Time 100 Hours Test No. MTC-3 Lubricant No. AL-9841-L

3 Left Antithrust

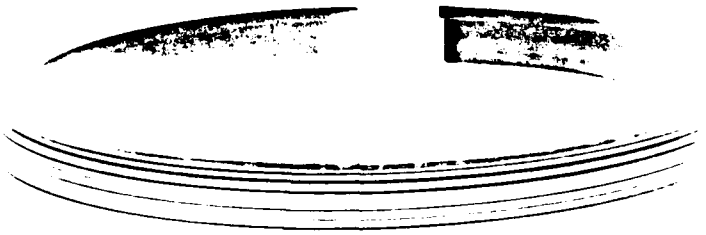
Figure 13. METHOD 354

Condition of Compression Ring Face

Test Time 100 Hours Test No. MTC-3 Lubricant No. AL-9841-L



1 Right

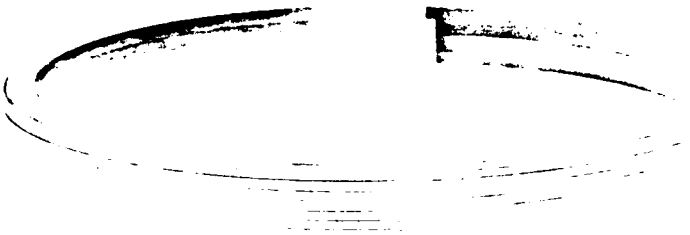


2 Right

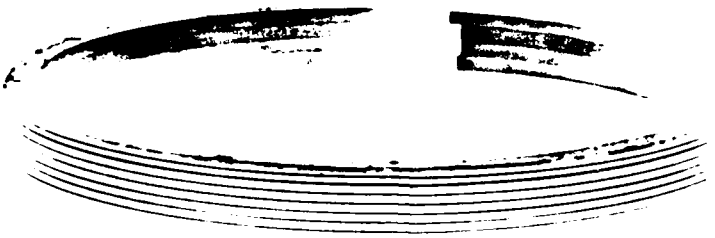
Figure 14. METHOD 354

Condition of Compression Ring Face

Test Time 100 Hours Test No. MTC-3 Lubricant No. AL-9841-L



3 Right

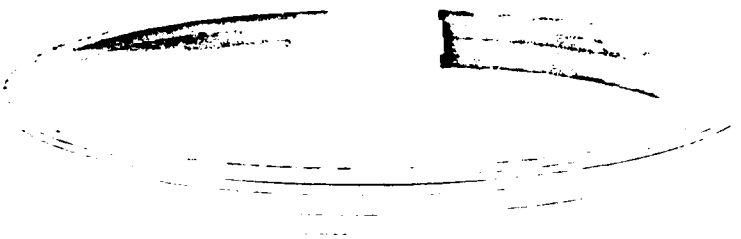


1 Left

Figure 15. METHOD 354

Condition of Compression Ring Face

Test Time 100 Hours Test No. MTC-3 Lubricant No. AL-9841-L



2 Left

3 Left

APPENDIX C

PERFORMANCE OF AL-8980-L LUBRICATING OIL IN A TWO-CYCLE DIESEL ENGINE UNDER STEADY-STATE TURBOSUPERCHARGED CONDITIONS

PERFORMANCE OF AL-8980-L LUBRICATING OIL IN A TWO-CYCLE DIESEL ENGINE UNDER STEADY-STATE TURBOSUPERCHARGED CONDITIONS

(Method 354 Fed. Test Method Std. 791B)

Engine Test Number: MTC-1 (Modified Test*)

Date Completed: 12 September 1980

Conducted For

U.S. Army Mobility Equipment Research and Development Command

Energy and Water Resources Laboratory

Fort Belvoir, Virginia

by

U.S. Army Fuels and Lubricants Research Laboratory

Southwest Research Institute

San Antonio, Texas 78284

* Modified Test

This test used the cast iron block version of the DD6V-53T engine. Changes include a cast iron engine block, a 16-plate oil cooler and 8-plate auxiliary oil cooler.

TABLE 1

6V-53T 6D-151056
BUILD-UP ENGINE MEASUREMENTS

Measurements*	Min.	Max.	Avg.	Specified Limits**
Connecting rod bearing clearance	0.0035	0.0040	0.0038	0.0010-0.0040
Cylinder liner block bore				
Taper	0.0000	0.0005	0.0002	0.0015 max.
Out-of-round	0.0000	0.0009	0.0004	0.0015 max.
Inside Diameter	4.3568	4.3581	4.3574	4.3565-4.3575 New 4.3595 max.
Cylinder liners (installed)				
Taper	0.0000	0.0007	0.0003	0.0015 max.
Out-of-round	0.0000	0.0009	0.0003	0.0015 max.
Inside diameter	3.8751	3.8762	3.8756	3.8752-3.8767
Piston to liner fit	0.0072	0.0087	0.0079	0.0060-0.0095
Piston diameter	3.8673	3.8684	3.8678	3.8669-3.8691
Fire Ring				
End gap	0.028	0.039	0.034	0.020-0.046
Side clearance	0.003	0.004	0.003	0.003-0.006
#1 Compression ring				
End gap	0.024	0.036	0.031	0.020-0.046
Side clearance	0.007	0.009	0.008	0.007-0.010
#2 & #3 Compression ring				
End gap	0.025	0.039	0.032	0.020-0.046
Side clearance	0.005	0.006	0.006	0.005-0.010
Oil rings				
End gap	0.018	0.020	0.019	0.010-0.025
Side clearance	0.002	0.004	0.003	0.0015-0.0055

* All dimensions given are in inches.
** Limits on new parts unless maximum wear limit specified.

TABLE 2

OPERATING DATA SHEET

Test Run at U.S. Army Fuels & Lubricants Research Laboratory (SwRI)

Test Oil: AL-8980-L, MC-520, Imperial OE/HDO-30 Test Fuel: 1-H CAT

Test No.: MTC-1 Test Stand: 5 Engine No.: 6D-151056

Test Hours: 100 Date Started: 8 September 1980 Completed: 12 September 1980

Total Downtime: 5.9 Hrs Scheduled; 0 Hrs Unscheduled

	Min.	Max.	Avg.
Engine Speed, rpm	2800	2802	2800.48
Load, lb	97.1	104	99.32
Output, Bhp	234	249.5	238.33
Fuel Rate, lb/min	1.61	1.72	1.64
Oil Consumption, lb/hr			.5933
Temperature, °F			
Jacket-in	160	165	163.06
Jacket-out	173	176	174.75
Oil Sump	242	250	246.16
Inlet Air (compressor)	85	100	92.95
Airbox	273	285	280.34
Exhaust before turbo	820	880	854.55
Exhaust after turbo	720	770	751.80
Fuel at filter (secondary)	89	97	90.78
Pressures			
Compressor suction, in. H_2O	6.1	6.5	6.26
Compressor discharge, psi	10.0	11.1	10.48
Blower discharge (airbox), psi	16.0	17.5	16.77
Exhaust before turbo, psi	12.0	13.5	12.79
Exhaust after turbo, in. Hg	2.0	2.4	2.18
Oil gallery, psi	40.0	44.0	41.88
Fuel at filter, psi	58.0	60.0	59.36
Blowby, in. H_2O	0.95	1.13	1.03

Date _____ Signed _____

Approved Laboratory USAFLRL

TABLE 3

RATING DATA SHEET

Test Run at U.S. Army Fuels & Lubricants Research Laboratory (SwRI)

Test Oil: AL-8980-L, MC-520, Imperial OE/HDO-30 Test Fuel: 1-H CAT

Test No.: MTC-1 Test Stand: 5 Engine No.: 6D-151056

Test Hours: 100 Date Started: 8 September 1980 Completed: 12 September 1980

A. Cylinder Liner Ratings

Intake Port Plugging

Cylinder No.	Restriction, %
1L	< 1
2L	< 1
3L	< 1
1R	< 1
2R	< 1
3R	< 1
Average	< 1

Scuffing, Glazing, and Lacquer*

Cylinder No.	Scuffing, %			Glazing, %	Lacquer, %
	Thrust	Anti-Thrust	Total		
1L	5	10	7.5	0	100
2L	10	5	7.5	5	95
3L	5	5	5	5	95
1R	0	0	0	5	95
2R	20	10	1.5	5	95
3R	5	5	5	5	95
Average	7.5	5.83	6.7	4.16	95.83

* Total Ring Travel Area

B. Piston Ratings

Ring Sticking and Condition*

Cylinder No.	Ring			
	Fire	No. 1	No. 2	No. 3
1L	F 55	F-0	F-0	F-0
2L	S 50	F-0	F-0	F-0
3L	S 20	F-5	F-10	F-5
1R	S 35	F-0	F-0	F-0
2R	F 15	F-10	F-25	F-10
3R	5%P 60	F-0	F-5	F-5

* Numbers denote % area ring face burn F = free P = pinched
S = sluggish HS = hot stuck

TABLE 3 (Cont'd)

Ring Groove Carbon Filling and Oil Groove Lacquer

Cylinder No.	Groove Filling, %				Oil Groove Lacquer (Demerit)	
	Fire	No. 1	No. 2	No. 3	Upper	Lower
1L	10	15	0	0	3	3
2L	10	10	0	0	3	3
3L	15	65	2	0	3	3
1R	10	15	0	0	3	3
2R	5	10	0	0	3	3
3R	10	15	2	0	3	3

Land Description

Cylinder No.	Description
1L	Normal
2L	Normal
3L	Normal
1R	Normal
2R	Normal
3R	Normal

Skirt (Demerit)

Cylinder No.	Thrust	Anti-Thrust
1L	5.0 Lt. Scratches	4.5 Lt. Scratches
2L	5.4 Lt. Scratches	5.0 5% Scuff & Lt. Scratches
3L	5.5 10% Scuff & Scratches	5.5 Lt. Scratches
1R	5.5 Lt. Scratches	5.2 Lt. Scratches
2R	5.5 Lt. Scratches	5.2 Lt. Scratches
3R	5.0 30% Scuff & Scratches	5.5 Lt. Scratches

C. Other Ratings

Combustion Chambers With Exhaust Valves*

Cylinder No.	Description
1L	10%C-15%B-15%A-60%$\frac{1}{2}$A
2L	5%D-20%C-20%B-20%A-35%$\frac{1}{2}$A
3L	5%D-50%C-10%B-20%A-25%$\frac{1}{2}$A
1R	50%D-20%C-15%B-10%A-5%$\frac{1}{2}$A
2R	10%D-50%C-20%B-10%A-10%$\frac{1}{2}$A
3R	10%D-50%C-10%B-20%A-10%$\frac{1}{2}$A

* All Hard Carbon; Depths A-B-C-D

TABLE 3 (Cont'd)

D. Interim Inspections

Zero Test Hours	Inspection	Zero Test Hours	Inspection
1L	Normal	1R	Normal
2L	Normal	2R	Normal
3L	Normal	3R	Normal

24 Test Hours	Inspection	24 Test Hours	Inspection
1L	Lt Scuffing F*&B*	1R	Normal
2L	Normal	2R	Lt Glazing B
3L	Lt Scuffing B	3R	Lt Scuffing B

48 Test Hours	Inspection	48 Test Hours	Inspection
1L	Lt to Med glazing of liner	1R	Normal
2L	Normal	2R	Lt to med glazing of liner
3L	Lt Scuffing & glazing B	3R	Med to hvy glazing of liner

72 Test Hours	Inspection	72 Test Hours	Inspection
1L	Lt to med glazing of liner	1R	Lt to med glazing of liner
2L	Lt glazing of liner	2R	Med to hvy glazing of liner
3L	Lt scuffing & glazing B	3R	Med to hvy glazing of liner

*F = Front side of cylinder liner
*B = Back side of cylinder liner

E. Legend

Abbreviations	Definitions
T-Side	Thrust side of cylinder liner or piston skirt. (Inboard left bank and outboard right bank).
AT-Side	Anti-thrust side of cylinder liner or piston skirt (Side opposite thrust side).
Lt	Light

TABLE 3 (Cont'd)

Abbreviations	Definitions
Med	Medium
Hvy	Heavy
P. Melt	Melting of the plating on the piston surface.
Sct	Scratching
Frt	Front of piston or liner
Rr	Rear of piston or liner
Normal	All components considered normal, unless specified otherwise. This means rings are free, only light scuffing of liner and piston skirts, hard carbon on fire lands and lacquer on other ring lands.

Date _____ Signed _____

Approved Laboratory USAFLRL

TABLE 4.
OIL ANALYSIS DATA SHEET

Test Run at U.S. Army Fuels & Lubricants Research Laboratory (USAFLRL)

Test Oil - AL-8980-L, MC 520, Imperial OE/HDO-30 Test Fuel: 1-H CAT

Test No. MTC-1 Test Stand 5 Engine No. 6D-151056

Test Hours 100 Date: Started 8 September 1980 Completed 12 September 1980

		Test Hour Sample							
Determinaton	New Oil	12	24	36	48	60	72	84	100
Viscosity, cSt									
at 40°C	109.11	-	136.71	-	154.62	-	165.45	-	167.05
at 100°C	11.65	-	13.47	-	14.57	-	15.16	-	15.86
Total Acid Number	2.30	-	2.88	-	3.13	-	3.31	-	3.38
Total Base Number	13.3	-	8.24	-	6.67	-	7.27	-	7.20
Sulfated Ash, %	1.6	-	1.98	-	2.05	-	2.06	-	2.13
Flash Point, °C	223	-	227	-	234	-	218	-	218
Iron Content, ppm	-	18	23	23	20	25	27	30	18

- Not determined

Date _____ Signed _____

Approved Laboratory _____ USAFLRL _____

TABLE 5

6V-53T
Test MTC-1
Lubricant: AL-8980-L

WEAR MEASUREMENTS

Cylinder Liner Bore Diameter Change*

	Cylinder Number					
	1L		2L		3L	
	T-AT**	F-B**	T-AT	F-B	T-AT	F-B
Top	+0.0005	-0.0004	+0.0002	-0.0002	+0.0006	-0.0005
Middle	+0.0001	-0.0002	-0.0001	-0.0002	+0.0001	-0.0001
Bottom	-0.0002	-0.0005	-0.0002	-0.0001	-0.0001	0.0000

	Cylinder Number					
	1R		2R		3R	
	T-AT	F-B	T-AT	F-B	T-AT	F-B
Top	+0.0003	-0.0003	+0.0002	-0.0001	+0.0004	0.0000
Middle	+0.0002	+0.0003	+0.0001	+0.0005	0.0000	+0.0003
Bottom	+0.0001	0.0000	-0.0001	-0.0001	-0.0005	+0.0005

Average Change

	T-AT	F-B
Top	+0.0004	-0.0003
Middle	+0.0001	+0.0001
Bottom	-0.0002	0.0000

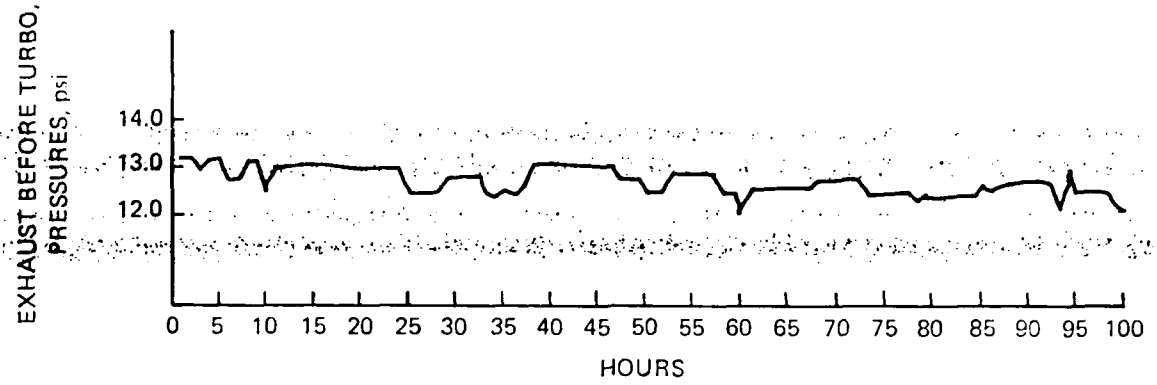
Overall Average Change: +0.0000

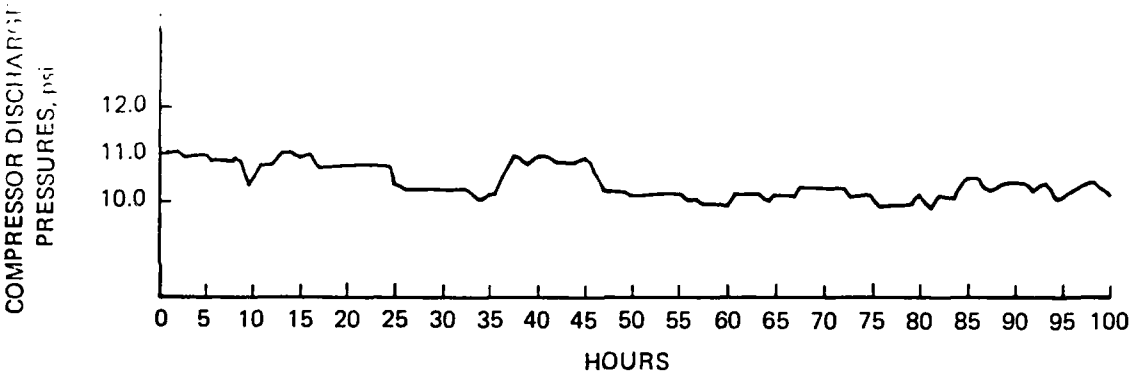
Piston Ring End Gap Change

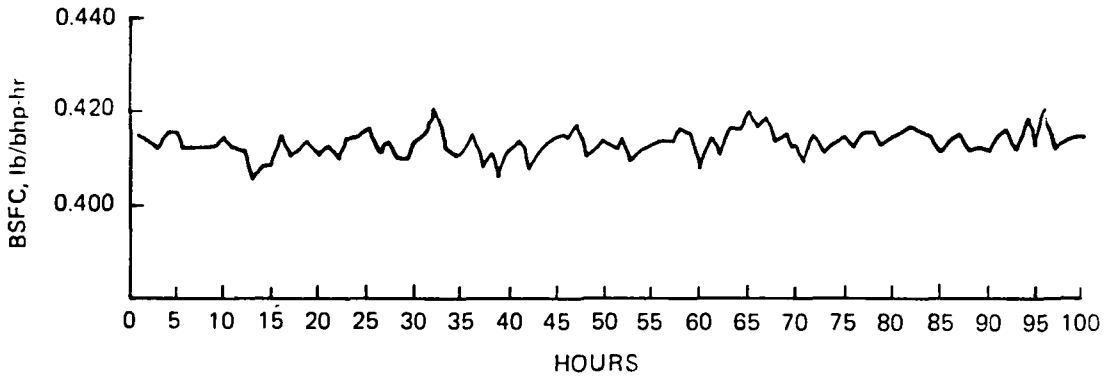
Ring Number	1L	2L	3L	1R	2R	3R	Average Change
1	-0.001	+0.001	+0.001	-0.002	0.000	+0.001	0.0000
2	-0.002	-0.001	-0.001	0.000	-0.002	-0.001	-0.0012
3	0.000	0.000	0.000	0.000	+0.003	0.000	+0.0005
4	0.000	0.000	0.000	-0.001	-0.004	0.000	-0.0008
5	+0.004	+0.004	+0.004	+0.004	+0.004	+0.005	+0.0042
6	+0.001	+0.003	+0.003	Broken	+0.003	+0.003	+0.0026
7	0.000	+0.003	+0.002	Broken	+0.002	+0.003	+0.0020

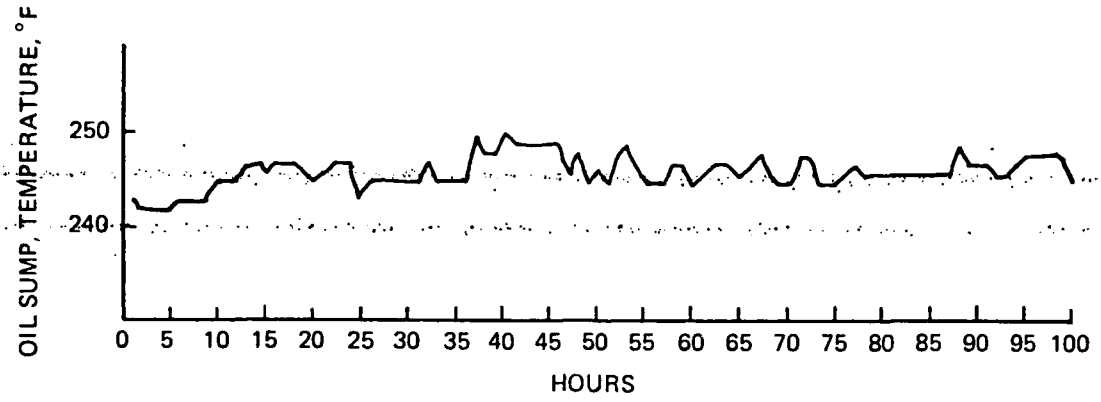
Overall Average Change: +0.0009

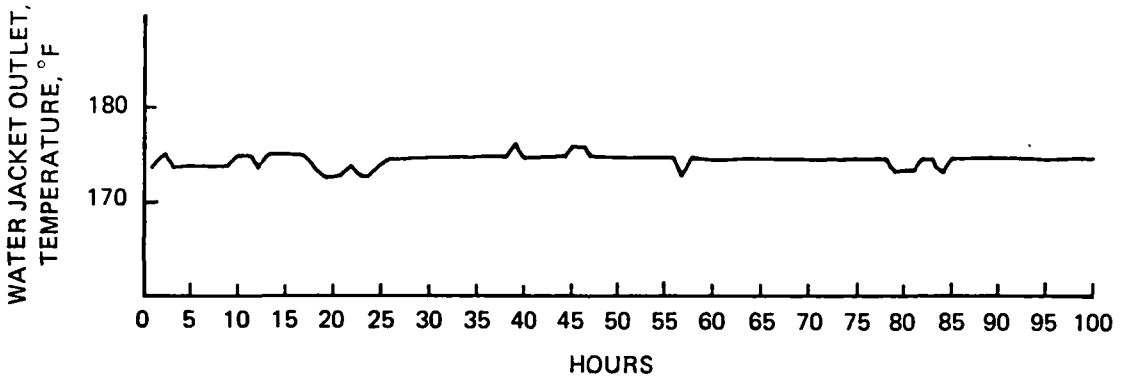
* All dimensions given are in inches.
** T-AT = Thrust-Antithrust Direction; F-B = Front-Back Direction

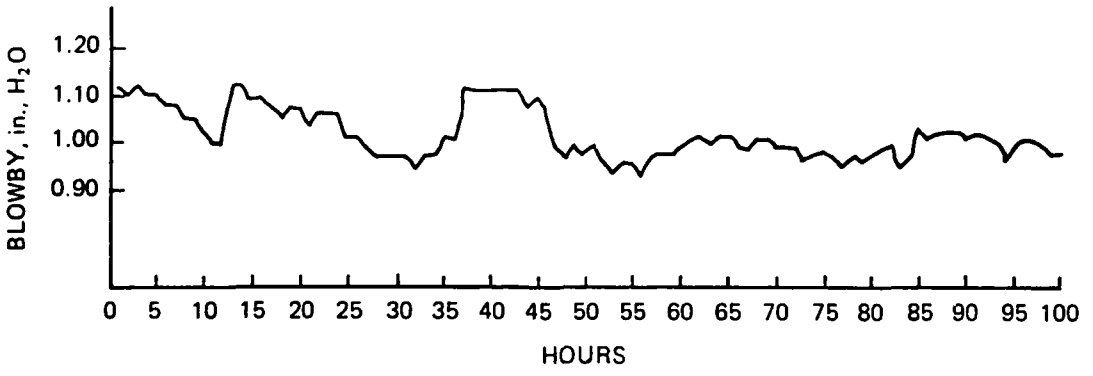

EXHAUST BEFORE TURBO, PRESSURES, psi
14.0
13.0
12.0
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
HOURS

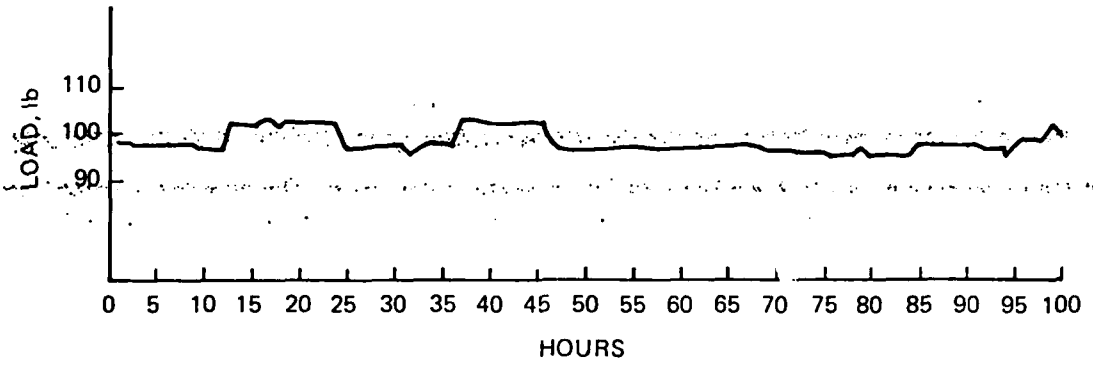

COMPRESSOR DISCHARGE PRESSURES, psi
12.0
11.0
10.0
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
HOURS

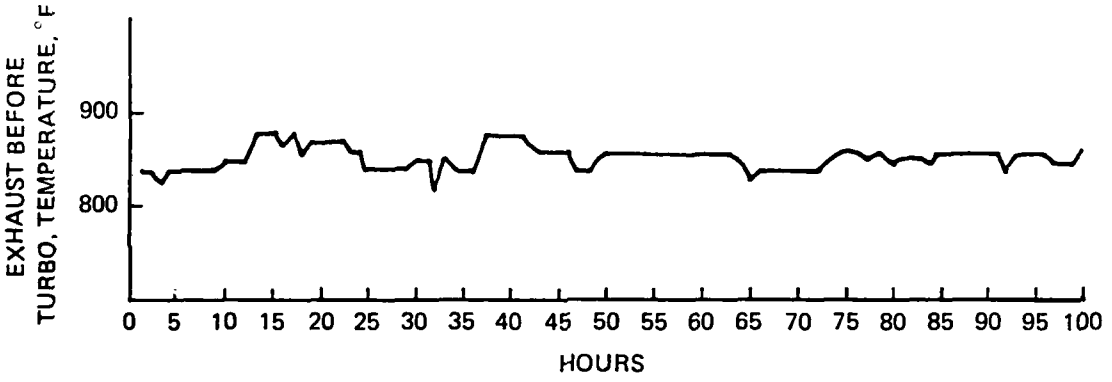

BSFC, lb/bhp-hr
0.440
0.420
0.400
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
HOURS


OIL SUMP, TEMPERATURE, °F
250
240
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
HOURS


WATER JACKET OUTLET, TEMPERATURE, °F
180
170
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
HOURS


BLOWBY, in., H_2O
1.20
1.10
1.00
0.90
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
HOURS


LOAD, lb
110
100
90
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
HOURS


EXHAUST BEFORE TURBO, TEMPERATURE, °F
900
800
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
HOURS

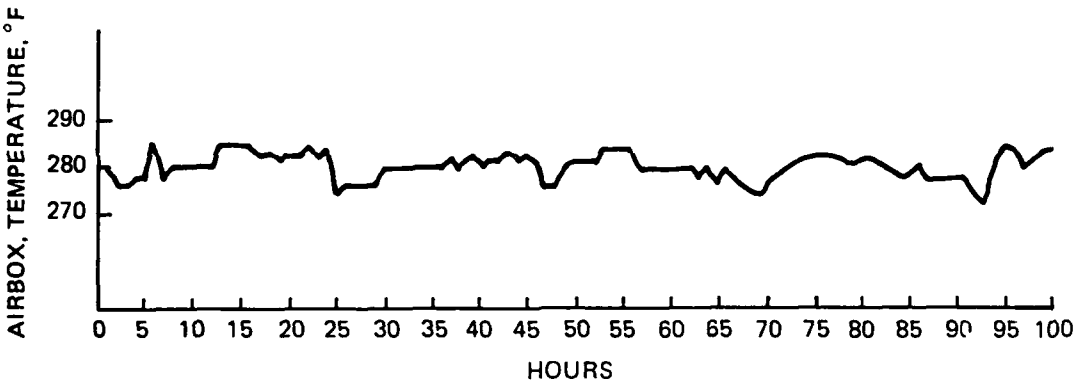
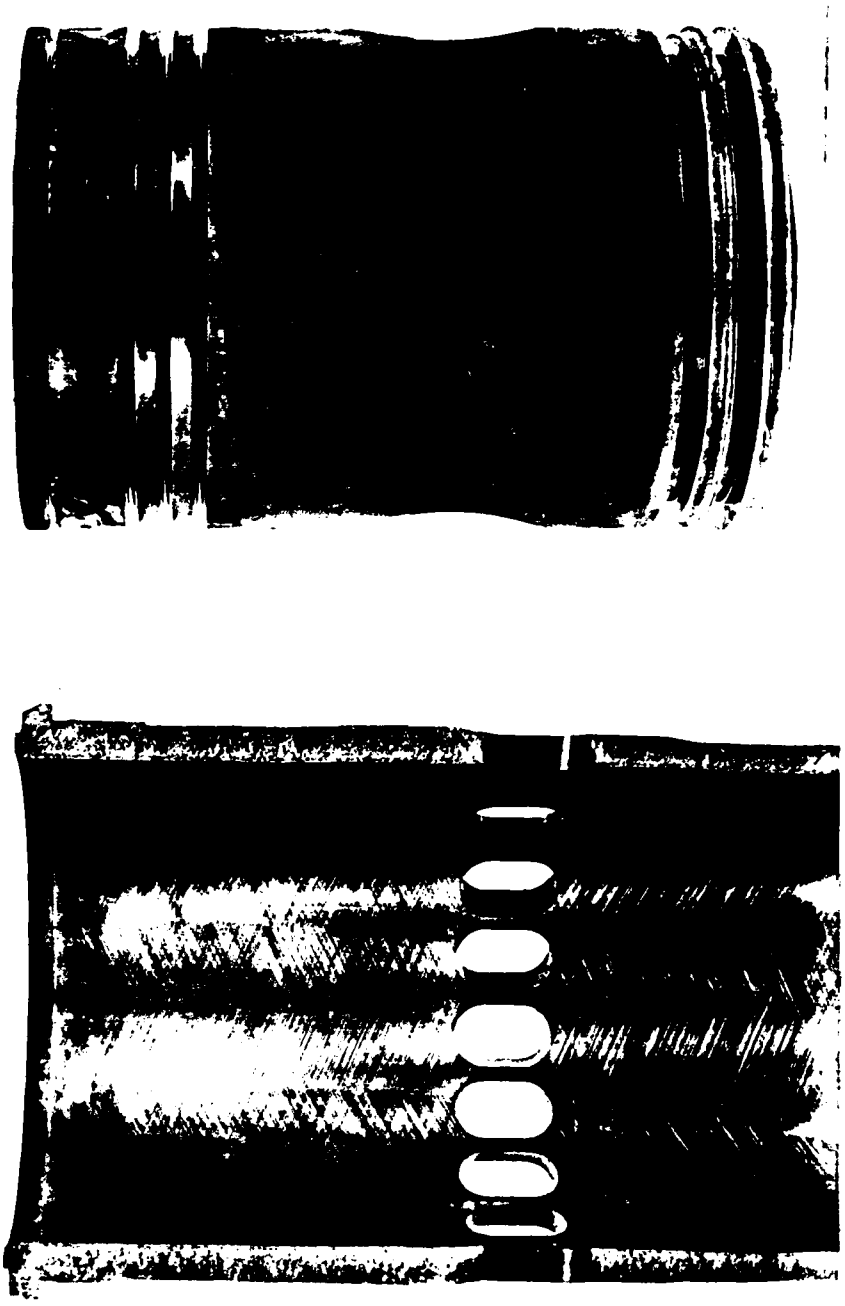

AIRBOX, TEMPERATURE, °F
290
280
270
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
HOURS

Figure 1. METHOD 354

Condition of Piston and Cylinder Liner

Test Time 100 hours Test No. MTC-1 Lubricant AL-8980-L MC-520 Imperial OE/HDO-30

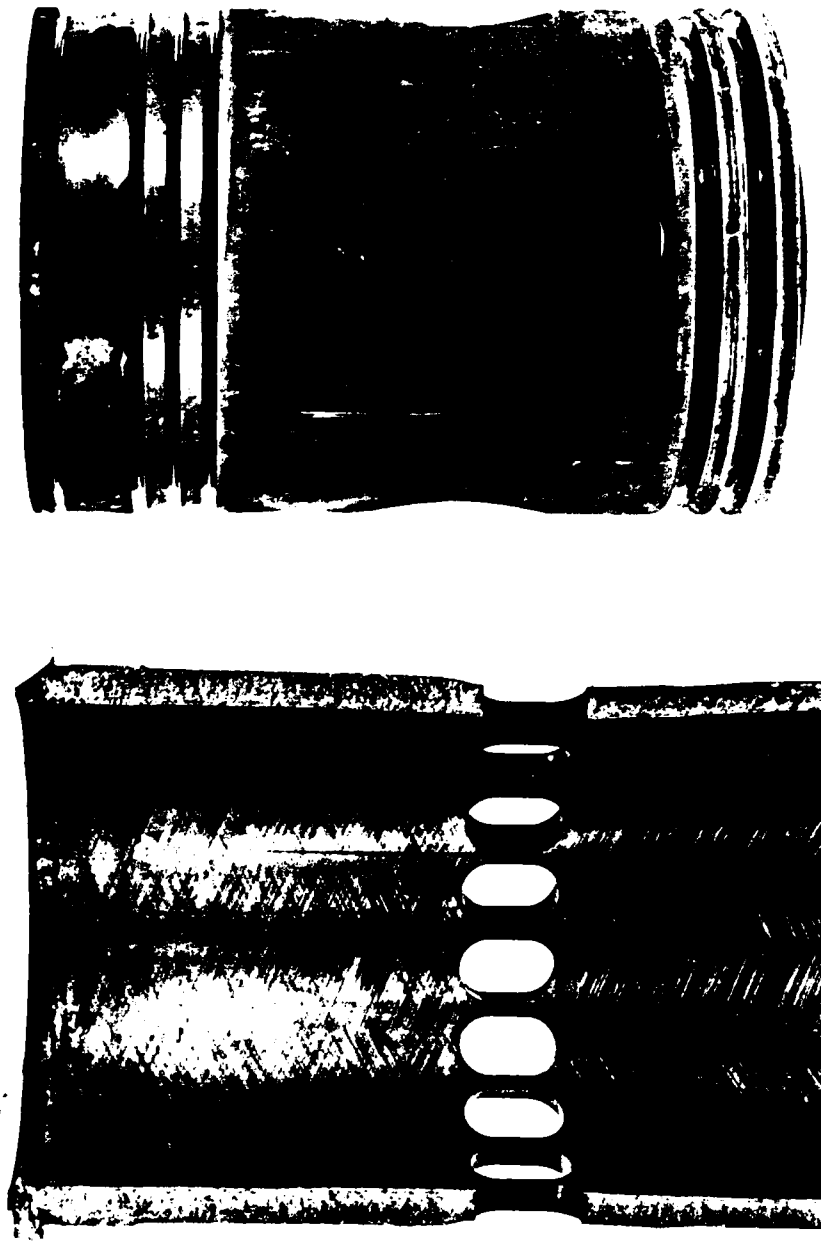


1 Right Thrust

Figure 2. METHOD 354

Condition of Piston and Cylinder Liner

Test Time 100 hours Test No. MTC-1 Lubricant AL-8980-L MC-520 Imperial OE/HDO-30

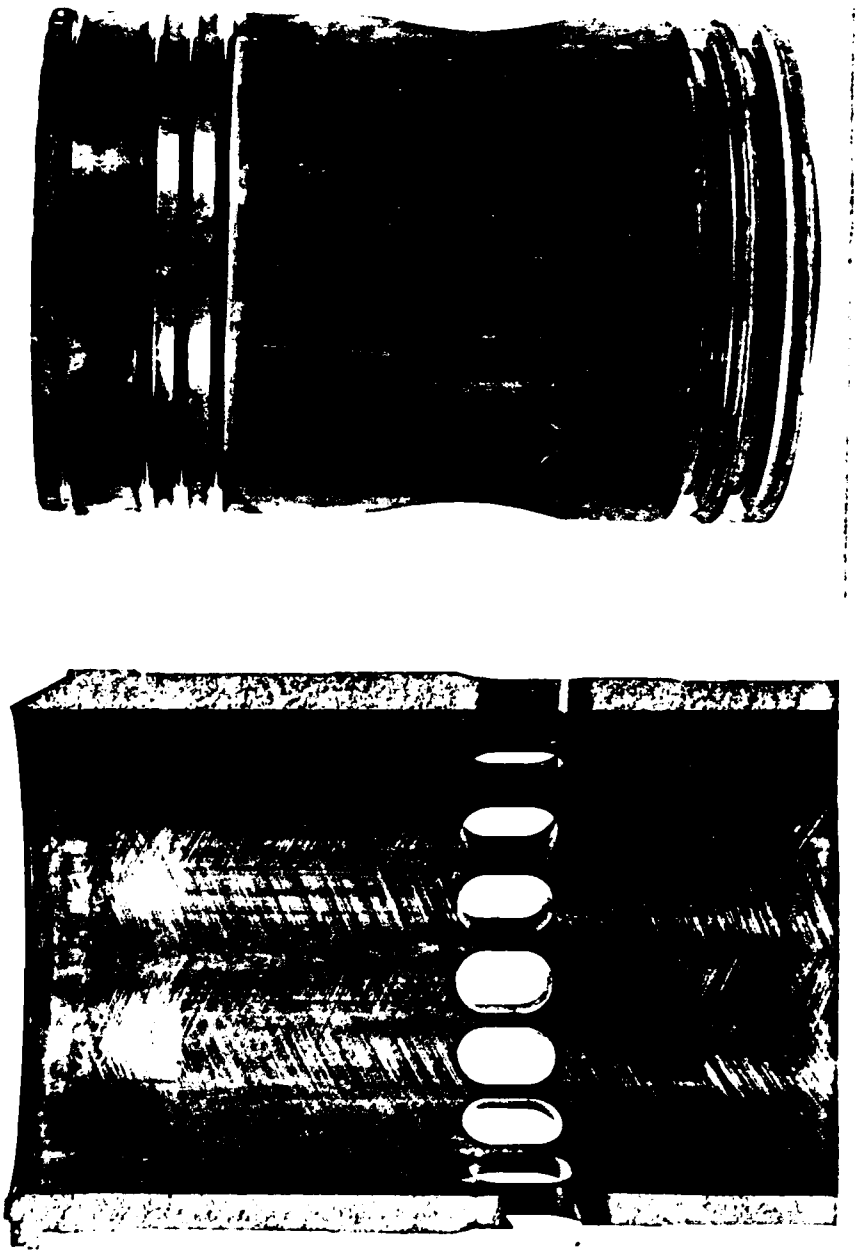


1 Right Anti-Thrust

Figure 3. METHOD 354

Condition of Piston and Cylinder Liner

Test Time 100 Hours Test No. MTC-1 Lubricant AL-8980-L MC-520 Imperial OE/HDO-30

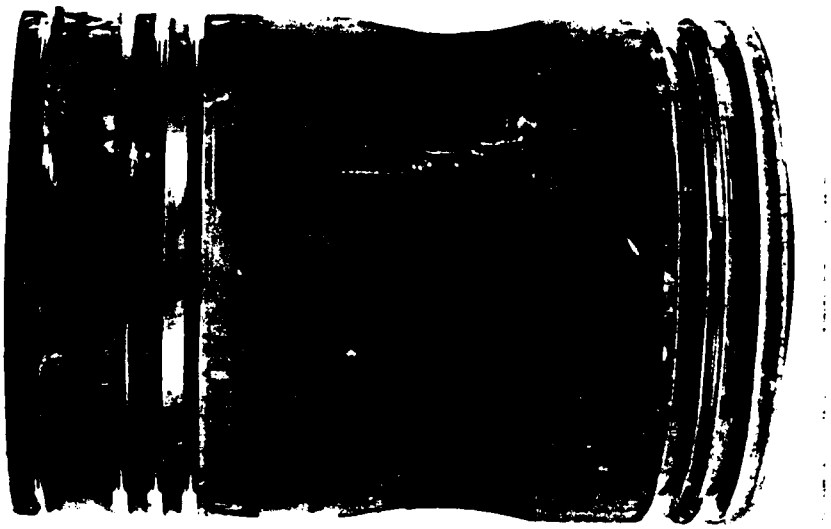


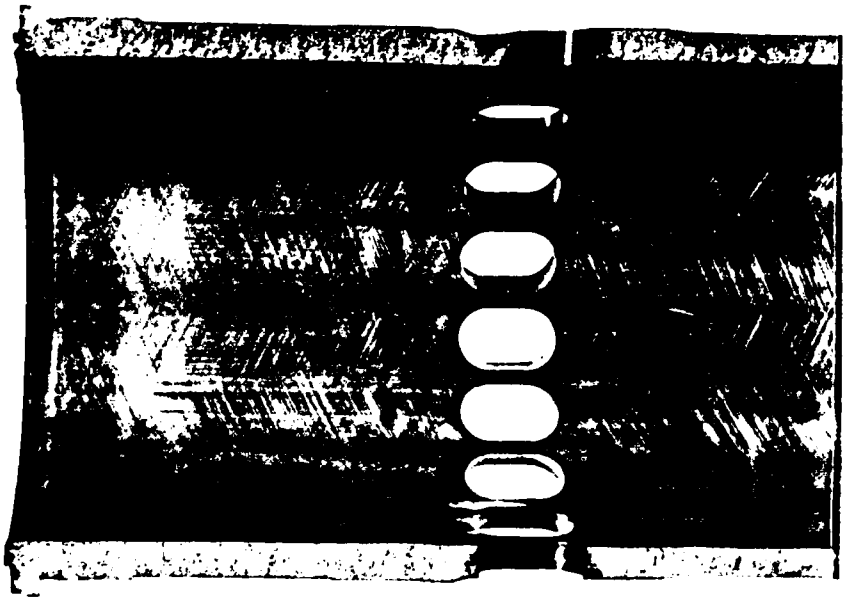
2 Right Thrust

Figure 4. METHOD 354

Condition of Piston and Cylinder Liner

Test Time 100 Hours Test No. MTC-1 Lubricant AL-8980-L MC-520 Imperial OE/HDO-30



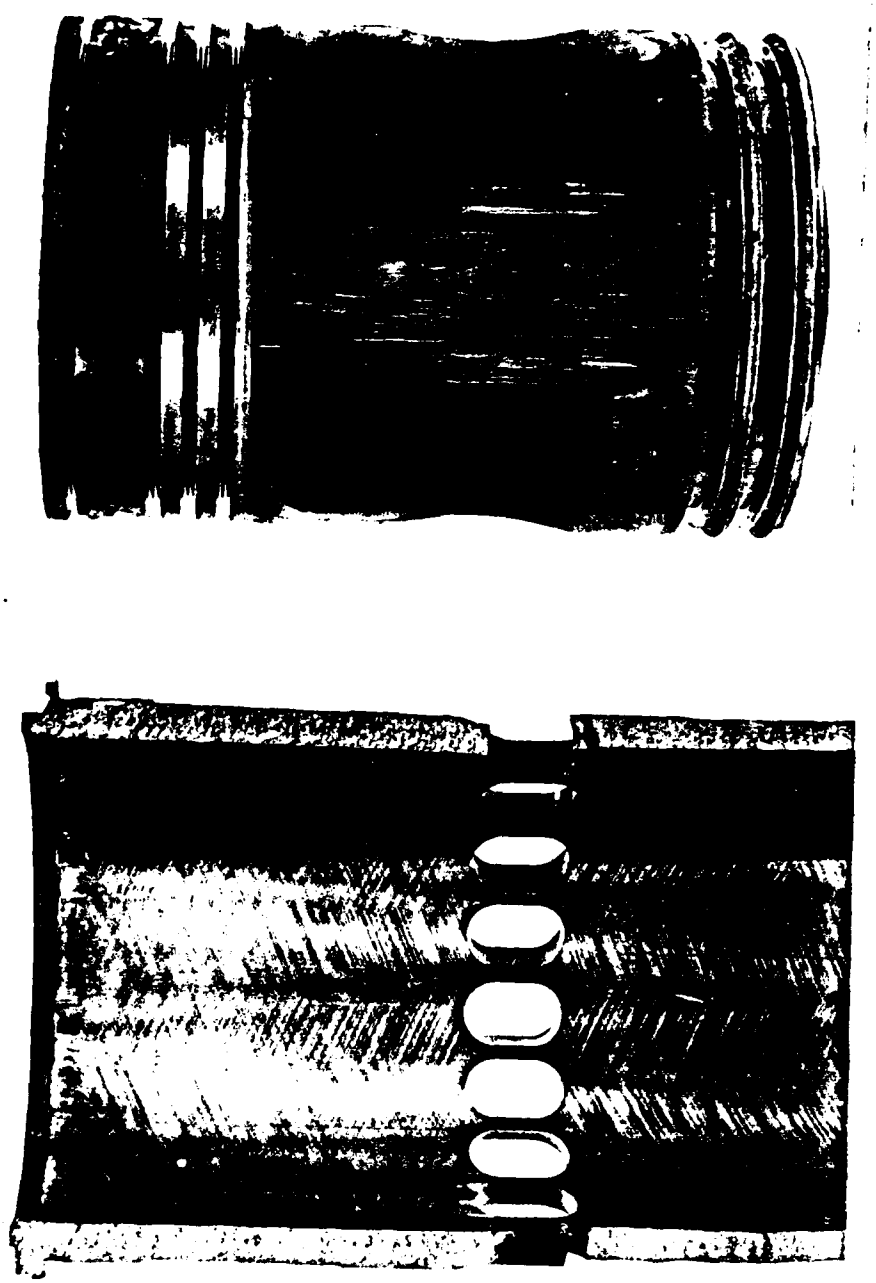


2 Right Anti-Thrust

Figure 5. METHOD 354

Condition of Piston and Cylinder Liner

Test Time 100 Hours Test No. MTC-1 Lubricant AL-8980-L MC-520 Imperial OE/HDO-30

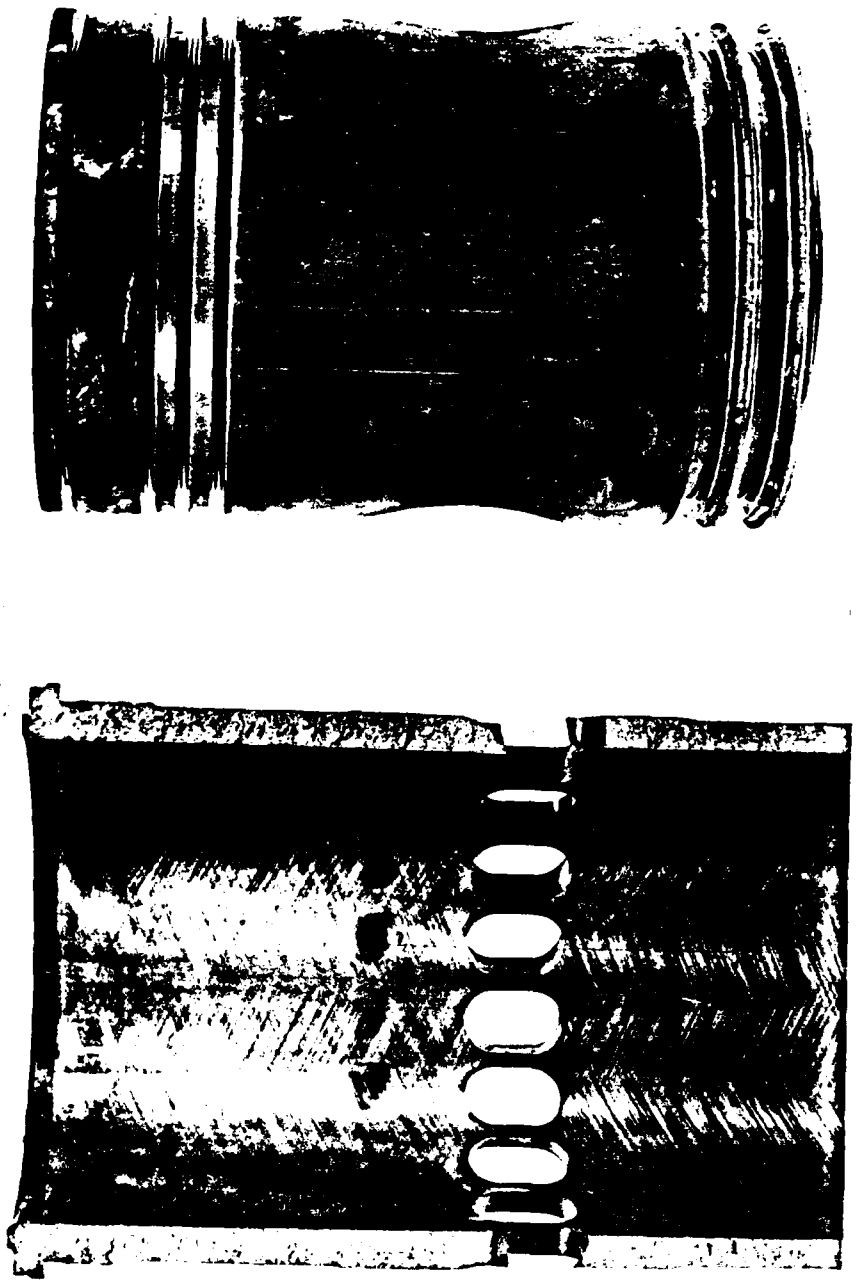


3 Right Thrust

Figure 6. METHOD 354

Condition of Piston and Cylinder Liner

Test Time 100 Hours Test No. MTC-1 Lubricant AL-8980-L MC-520 Imperial OE/HDO-30

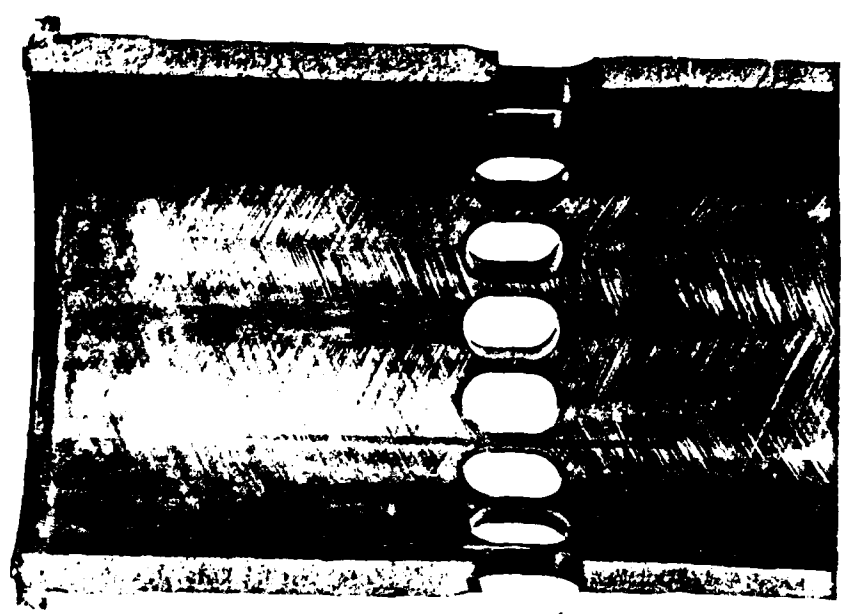


3 Right Anti-Thrust

Figure 7. METHOD 354

Condition of Piston and Cylinder Liner

Test Time 100 Hours Test No. MTC-1 Lubricant AL-8980-L MC-520 Imperial OC/HDO-30

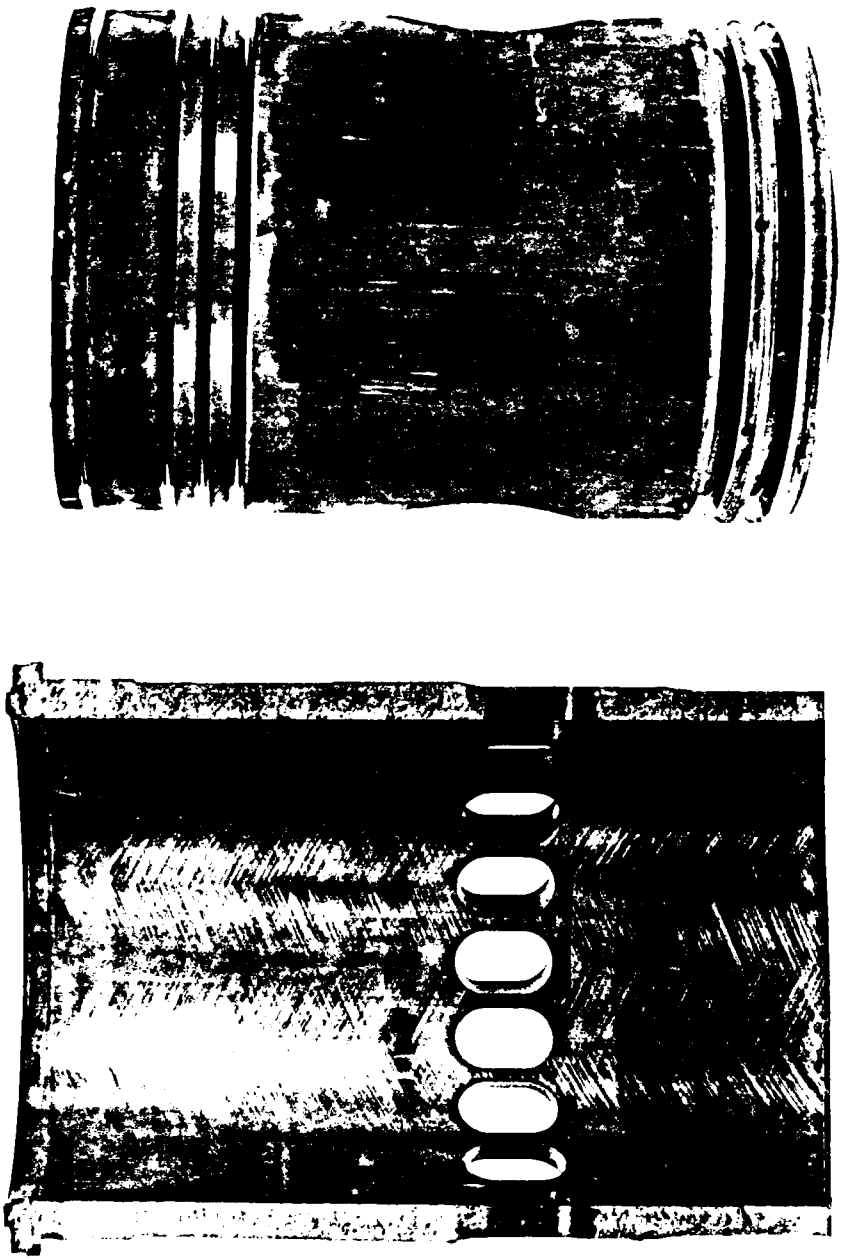


1 Left Thrust

Figure 8. METHOD 354

Condition of Piston and Cylinder Liner

Test Time 100 Hours Test No. MTC-1 Lubricant AL-8980-L MC-520 Imperial OE/HDO-30



1 Left Anti-Thrust

AD-A127 239 EVALUATION OF FOUR LUBRICANTS USING A MODIFIED FEDERAL TEST METHOD 354 TE..(U) SOUTHWEST RESEARCH INST SAN ANTONIO TX ARMY FUELS AND LUBRICA.. 2/2

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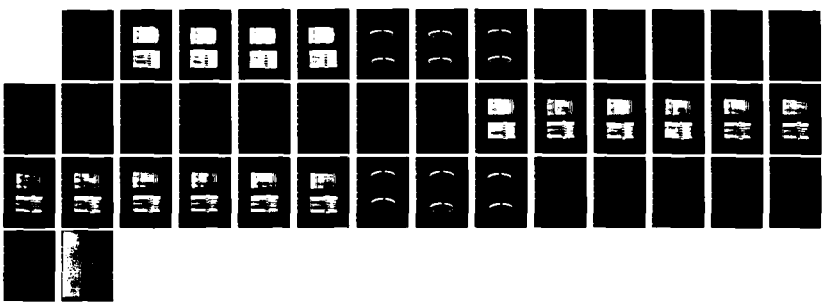
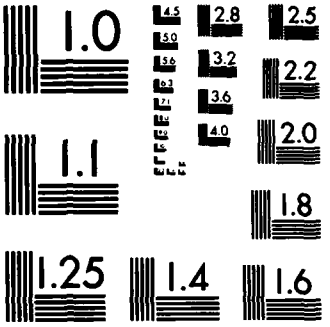


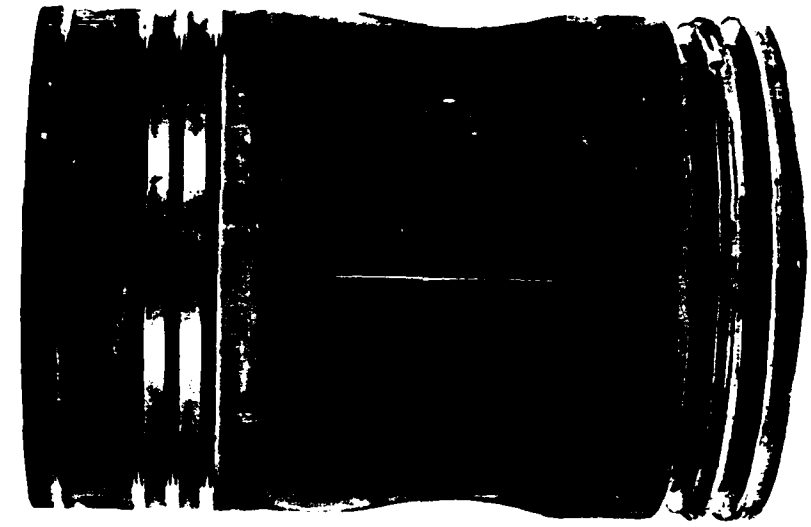


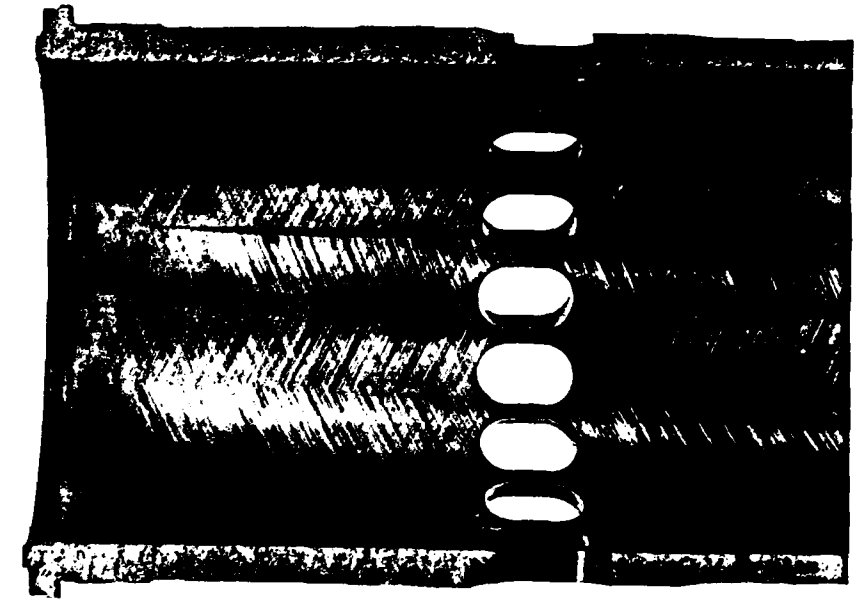
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Figure 9. METHOD 354

Condition of Piston and Cylinder Liner

Test Time 100 Hours Test No. MTC-1 Lubricant AL-8980-L MC-520 Imperial OE/HDO-30



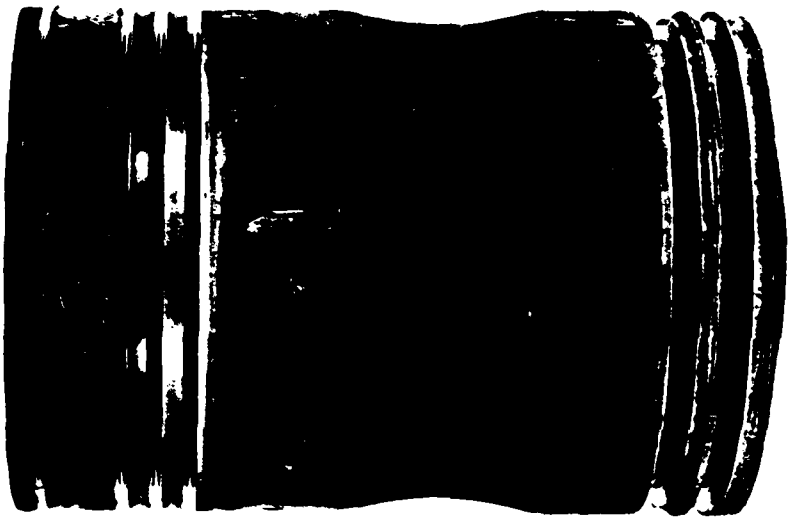


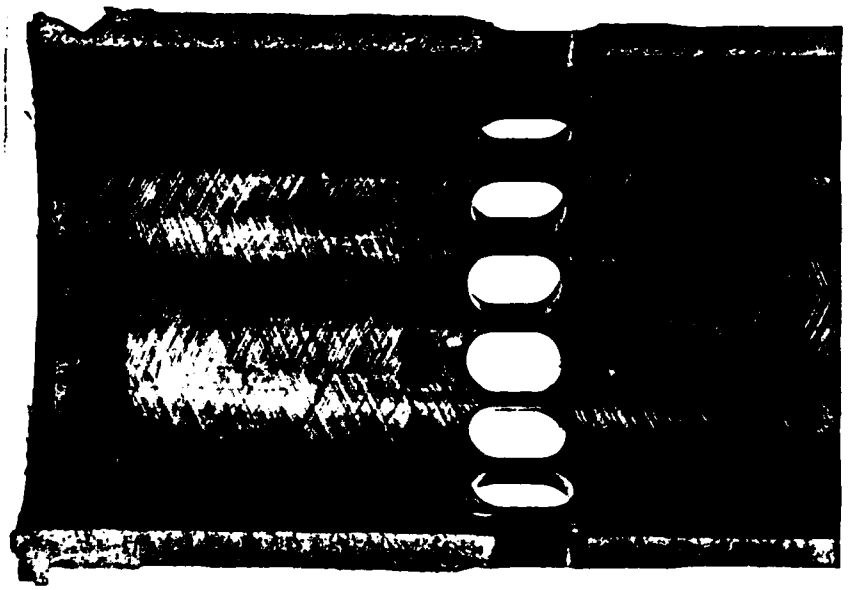
2 Left Thrust

Figure 10. METHOD 354

Condition of Piston and Cylinder Liner

Test Time 100 Hours Test No. MTC-1 Lubricant AL-8980-L MC-520 Imperial OE/HDO-30



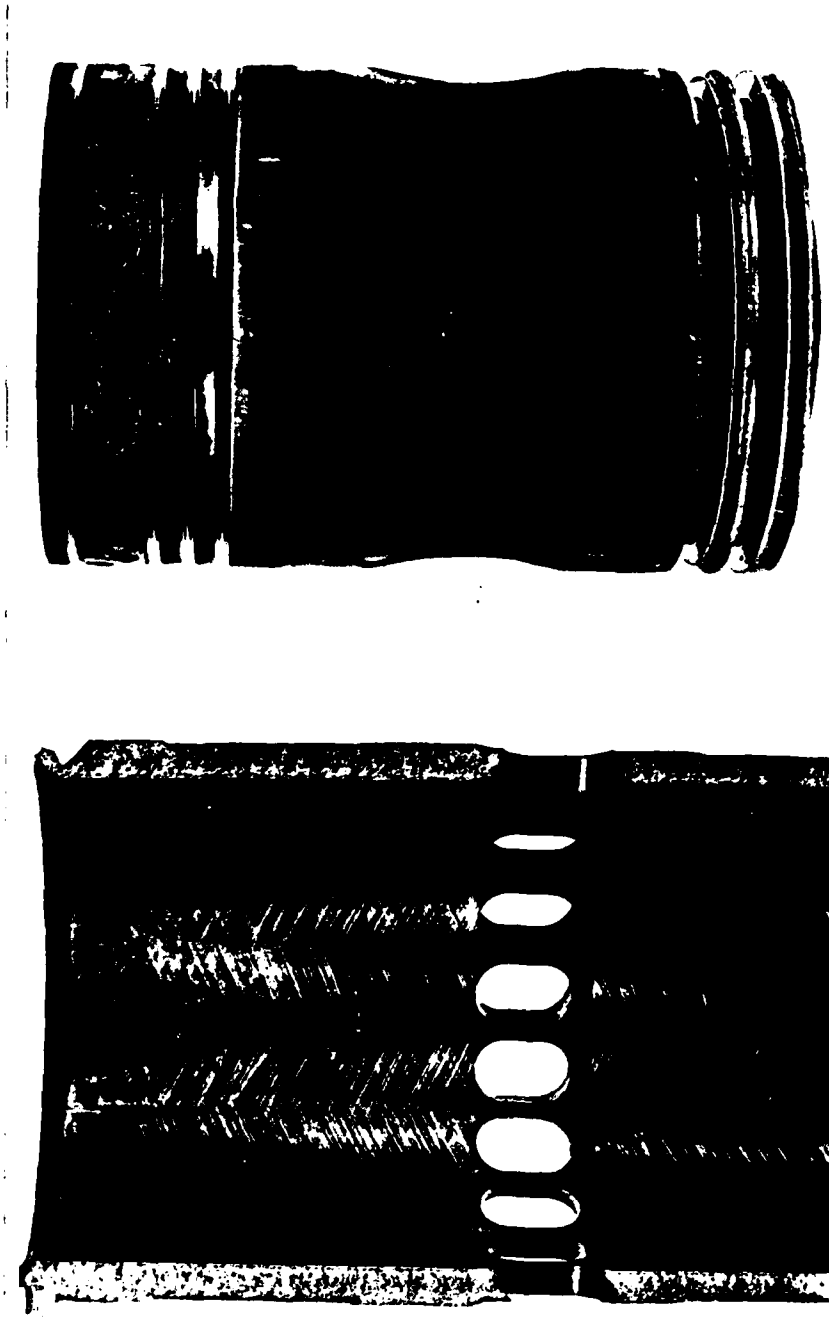


2 Left Anti-Thrust

Figure 11. METHOD 354

Condition of Piston and Cylinder Liner

Test Time 100 Hours Test No. MTC-1 Lubricant AL-8980-L MC-520 Imperial OE/HDO-30

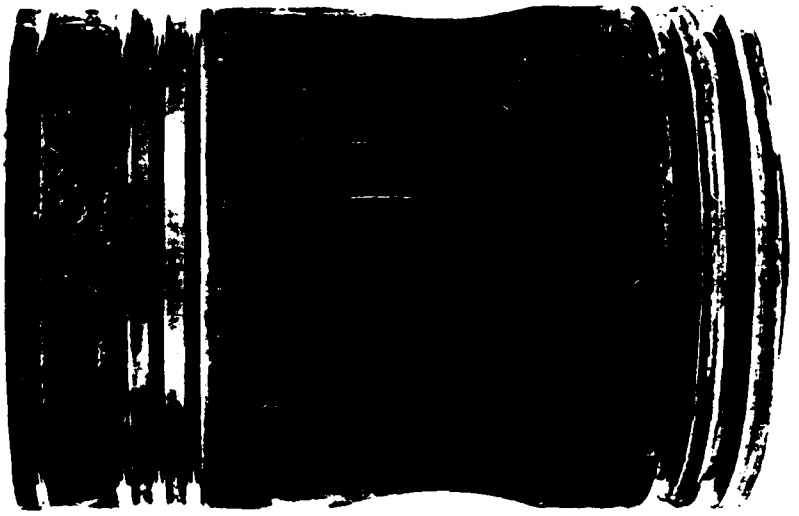


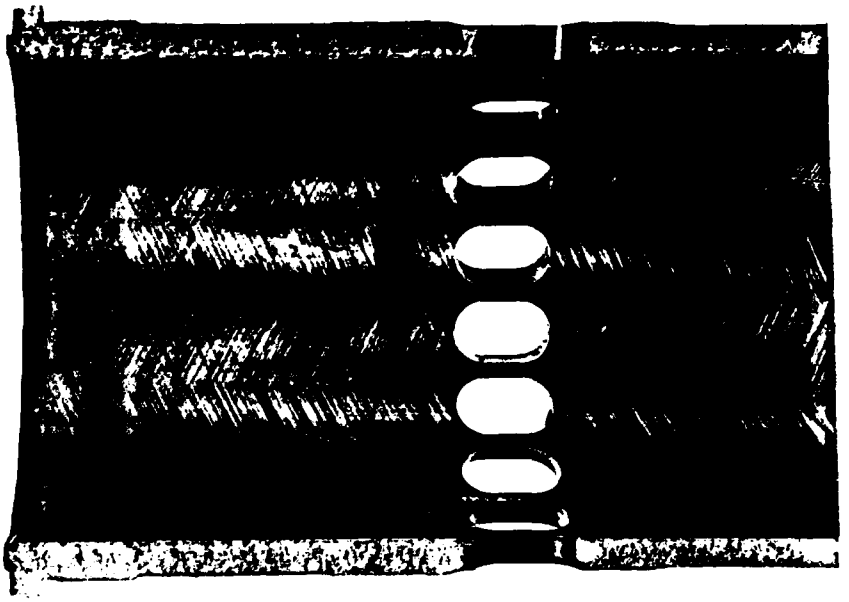
3 Left Thrust

Figure 12. METHOD 354

Condition of Piston and Cylinder Liner

Test Time 100 Hours Test No. MTC-1 Lubricant AL-8980-L MC-520 Imperial OE/HDO-30





3 Left Anti-Thrust

Figure 13. METHOD 354

Condition of Compression Ring Face

Test Time 100 Hours Test No. MTC-1 Lubricant AL-8980-L MC-520 Imperial OE/HDO-30

1 Right

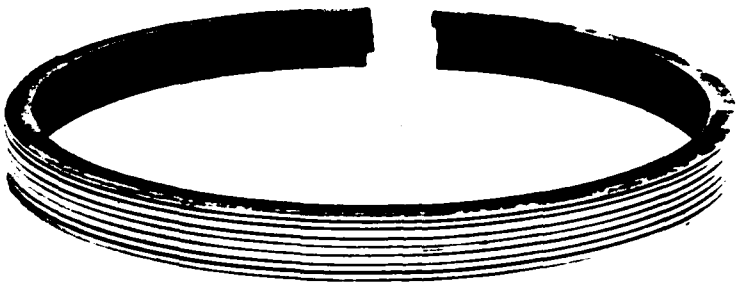
2 Right

Figure 14. METHOD 354

Condition of Compression Ring Face

Test Time 100 Hours Test No. MTC-1 Lubricant AL-8980-L MC-520 Imperial OE/HDO-30

3 Right

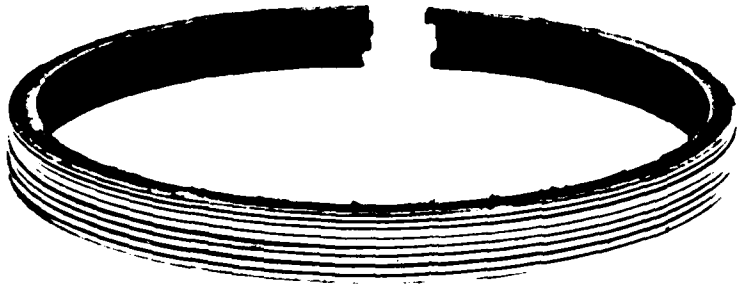


1 Left

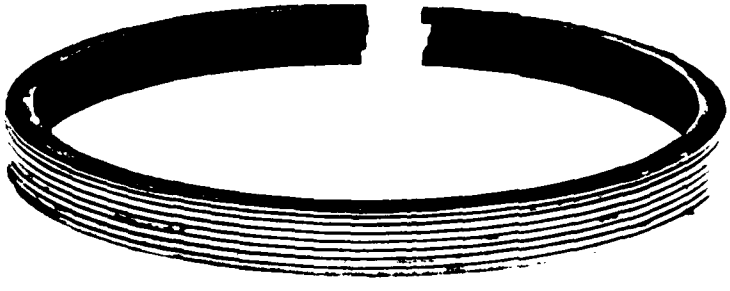
Figure 15. METHOD 354

Condition of Compression Ring Face

Test Time 100 Hours Test No. MTC-1 Lubricant AL-8980-L MC-520 Imperial OE/HDO-30



2 Left



3 Left

APPENDIX D

PERFORMANCE OF AL-01053-L LUBRICATING OIL IN A TWO-CYCLE DIESEL ENGINE UNDER STEADY-STATE TURBOSUPERCHARGED CONDITIONS

PERFORMANCE OF AL-10153-L LUBRICATING OIL IN A TWO-CYCLE DIESEL ENGINE UNDER STEADY STATE TURBOSUPERCHARGED CONDITIONS

(Method 354 Fed. Test Method Std. 791B)

Engine Test No: MTC-4 (Modified Test*)

Date Completed: 7 November 1980

Conducted For

U.S. Army Mobility Equipment Research and Development Command

Energy and Water Resources Laboratory

Fort Belvoir, Virginia

By

U.S. Army Fuels & Lubricant Research Laboratory

Southwest Research Institute

San Antonio, Texas 78284

Modified Test*

This test used the cast iron block version of the DD6V-53T engine. Changes include a cast iron engine block, a 16 plate oil cooler and an 8 plate auxiliary oil cooler.

TABLE 1

6V53T 6D-151056
BUILD-UP ENGINE MEASUREMENTS

	Measurements *			
	Min.	Max.	Avg.	Specified Limits**
Connecting rod bearing clearance	0.0024	0.0031	0.0029	0.0010 to 0.0040
Cylinder liner block bore				
Taper	0.0000	0.0004	0.0002	0.0015 max
Out-of-round	0.0000	0.0007	0.0003	0.0015 max
Inside diameter	4.3568	4.3579	4.3574	4.3565 - 4.3575 4.3595 max
Cylinder liners (installed)				
Taper	0.0000	0.0006	0.0003	0.0015 max
Out-of-round	0.0000	0.0008	0.0003	0.0015 max
Inside diameter	3.8754	3.8763	3.8758	3.8752 to 3.8767
Piston to liner fit[1]	0.0072	0.0088	0.0081	0.0060 to 0.0095
Piston diameter	3.8675	3.8682	3.8678	3.8669 to 3.8691
Fire ring				
End gap	0.034	0.041	0.036	0.020 to 0.046
Side clearance	0.003	0.004	0.0035	0.003 to 0.006
#1 Compression ring				
End gap	0.032	0.037	0.034	0.020 to 0.046
Side clearance	0.008	0.008	0.008	0.007 to 0.010
#2 & #3 Compression ring				
End gap	0.028	0.036	0.034	0.020 to 0.046
Side clearance	0.005	0.007	0.0058	0.005 to 0.010
Oil rings				
End gap	0.018	0.021	0.019	0.010 to 0.025
Side clearance	0.002	0.004	0.002	0.0015 to 0.0055

* All measurements are in inches

** Wear limits with new liners in a used block

[1] Thrust-Antithrust direction

TABLE 2

OPERATING DATA SHEET

Test Run at U.S. Army Fuels & Lubricants Research Laboratory (SwRI)

Test Oil: AL-10153-L Test Fuel: 1-H Cat

Test No. MTC-4 Test Stand 5 Engine No.6D-151056

Test Hours 100 Date: Started 3 November 1980 Completed 7 November 1980

Total Downtime 6.75 Hrs Scheduled; 0 Hrs Unscheduled

	Min.	Max.	Avg.
Engine speed, rpm	2799	2802	2800
Load, lbs	98	100	99
Output, BHp	235	240	238
Fuel rate, lb/min	1.60	1.67	1.62
Oil Consumption, lb/hr			.5059
Temperatures, °F			
Jacket-in	158	160	160
Jacket-out	160	172	170
Oil sump	235	245	240
Inlet air (compressor)	72	90	81
Airbox	243	274	259
Exhaust before turbo	720	880	809
Exhaust after turbo	700	870	730
Fuel at filter (secondary)	85	91	88
Pressures			
Compressor suction, in., H_2O	5.2	6.5	6.2
Compressor discharge, psi	6.1	10.8	9.7
Blower discharge, psi	12.1	18.0	17.1
Exhaust before turbo, psi	8.9	13.5	12.8
Exhaust after turbo, in., Hg	1.2	2.5	2.3
Oil gallery, psi	41.5	46.0	43.8
Fuel at filter, psi	71.0	72.2	71.7
Blowby, in., H_2O	.78	2.1	1.7

TABLE 3

RATING DATA SHEET

Test Run at U.S. Army Fuels & Lubricants Research Laboratory (SwRI)

Test Oil: AL-10153-L Test Fuel: 1-H CAT

Test No. MTC-4 Test Stand 5 Engine No. 6D-151056

Test Hours: 100 Date: Started 3 November 1980 Completed 7 November 1980

A. Cylinder Liner Ratings

Intake Port Plugging

Cylinder No.	Restriction,%
1 L	< 1
2 L	< 1
3 L	< 1
1 R	< 1
2 R	< 1
3 R	< 1
Average	< 1

Scuffing, GLazing, and Lacquer*

Cylinder No.	Scuffing, % Thrust	Scuffing, % Anti-Thrust	Scuffing, % Total Area Scuffed	Glazing,%	Lacquer, %
1 L#	10	10	10	0	60
2 L#	5	5	5	0	60
3 L#	15	10	12.5	0	60
1 R#	25	20	22.5	0	60
2 R#	30	10	20	5	55
3 R#	15	15	15	0	60
Average	16.7	11.7	14.2	1	59.2

*Total Ring Travel Area

#Some Light Vertical Lines

TABLE 3 - Continued

B. Piston Ratings

Cylinder No.	Ring Sticking and Condition* Ring Fire	No. 1	No. 2	No. 3
1 L	F#-1	F-<1	F-0	F-<1
2 L	F -1	F-0	F-0	F-0
3 L	5% P -1	F-0	F-0	F-<1
1 R	F-15	F-10	F-0	F#-5
2 R	5% P-50	F-100	F-100	F-90
3 R	F -2	F-0	F-<1	F-0

* Numbers denote % area ring face burn
\# Ring Face Chipped

F-Free
P-Pinched

Ring Groove Carbon Filling and Oil Groove Lacquer

Cylinder No.	Groove Filling, % Fire	No. 1	No. 2	No. 3	Oil Groove Lacquer (Demerit) Upper	Lower
1 L	20	5	0	0	5	5
2 L	20	5	0	0	5	5
3 L	5	15	0	0	5	5
1 R	15	35	0	0	5	5
2 R	10	20	0	0	5	5
3 R	15	70	0	0	5	5

Land Description

Cylinder No.	Description
1 L	Normal
2 L	Normal
3 L	Normal
1 R	Normal
2 R	Normal
3 R	Normal

Skirt (Demerit)

Cylinder No.	Thrust	Anti-Thrust
1 L	5.5-5% scuffing; Lt. Scr.	6.0-Very Lt. Scr.
2 L	6.2 - Lt. Scr.	5.5-5% Scuffing; Lt. Scr.
3 L	6.6-Lt. Scr.	5.5-Lt. Scr.
1 R	5.8-5% Scuffing; Lt. Scr.	5.5-Lt. Scr.
2 R	6.6-Lt. Scr.	5.8-Lt. Scr.
3 R	6.5-Lt. Scr.	6.0-Lt. Scr.

C. Other Ratings

Combustion Chambers

Cylinder No.	Description	Cylinder No.	Description
1 L	70%A, 30%½A, HC	1 R	75%A, 25%½A, HC
2 L	65%A, 35%½A, HC	2 R	50%A, 50%½A, HC
3 L	60%A, 40%½A, HC	3 R	30%A, 70%½A, HC

D. Interim Inspections

Zero Test Hours	Inspection
1 L	Normal
2 L	Normal
3 L	Normal
1 R	Normal
2 R	Normal
3 R	Normal

24 Test Hours	Inspection
1 L	Normal
2 L	Normal
3 L	Normal
1 R	Normal
2 R	Normal; med to hvy scuffing Rr of liner
3 R	Normal

48 Test Hours	Inspection
1 L	Normal; med to hvy glazing Frt & Rr of liner
2 L	Normal; hvy glazing Frt & Rr of liner
3 L	Normal; top compression ring stuck, med to hvy glazing Frt & Rr of liner

TABLE 3 - Continued

48 Test Hours	Inspection
1 R	Normal; Med glazing; Med to Hvy scuffing to Rr & AT-side of liner
2 R	Normal; Hvy scuffing to Rr & AT-side of liner
3 R	Normal; Hvy glazing to Frt & Rr of liner

72 Test Hours	Inspection
1 L	Normal; Hvy glazing to Frt & Rr of liner
2 L	Normal; Fire & top compression rings stuck; Hvy glazing Frt & Rr of liner
3 L	Normal; Lt to Med scuffing, Med. glazing of liner
1 R	Normal; Top compression ring stuck; Hvy scuffing to Frt, Med to Hvy glazing of liner
2 R	Normal; Top compression ring stuck; Hvy scuffing and glazing to Rr of liner
3 R	Normal; Hvy glazing to Frt & Rr of liner

E. Legend

Abbreviations	Definitions
T-side	Thrust side of cylinder liner or piston skirt. (Inboard left bank & outboard right bank).
AT-side	Anti-thrust side of cylinder liner or piston skirt. (Side opposite the thrust side).
Lt.	Light
Med.	Medium
Hvy.	Heavy
P. Melt	Melting of the plating on the piston surface.
Scr.	Scratching
Frt.	Front of piston or liner
Rr.	Rear of piston or liner
Normal	All components considered normal, unless specified otherwise. This means rings are free, only light scuffing of liner and piston skirts, hard carbon on fire lands, and lacquer on other ring lands.

TABLE 4

OIL ANALYSES DATA SHEET

Test Run at U.S. Army Fuels & Lubricants Research Laboratory (SwRI)

Test Oil - Al-10153-L | Test Fuel - 1-H Cat

Test No. MTC-4 | Test Stand 5 | Engine No. 6D-151056

Test Hours 100 | Date: Started 3 November 1980 | Completed 7 November 1980

		TEST HOUR SAMPLE							
Determination	New Oil	12	24	36	48	60	72	84	100
Viscosity, cSt									
at 40°C			69.06		72.07		75.19		79.14
at 100°C			10.37		10.66		10.96		11.35
Total Acid Number	2.34		2.75		3.31		3.42		4.05
Total Base Number	8.74		7.22		6.59		6.59		5.[illegible]
Sulfated Ash, %			1.07				1.21		1.[illegible]
Flash Point, °C			212				216		218
Iron Content, ppm		84	110	133	118	116	111	109	119

TABLE 5

Lubricant: AL-10153-L

WEAR MEASUREMENTS

Cylinder Liner Bore Diameter Change*

	Cylinder Number					
	1L		2L		3L	
	T-AT**	F-B**	T-AT	F-B	T-AT	F-B
Top	+ .0007	+.0001	+ .0008	+ .0002	+ .0005	+ .0002
Middle	+ .0003	+.0001	+ .0002	+ .0004	+ .0002	+ .0008
Bottom	- .0002	+.0001	+ .0002	+ .0002	+ .0003	+ .0004

	Cylinder Number					
	1R		2R		3R	
	T-AT	F-B	T-AT	F-B	T-AT	F-B
Top	+ .0010	+ .0006	+ .0011	+ .0012	+ .0004	+ .0004
Middle	+ .0004	+ .0004	+ .0007	+ .0001	+ .0005	+ .0004
Bottom	+ .0003	+ .0003	+ .0003	+ .0011	+ .0003	+ .0002

	Average Change	
	T-AT	F-B
Top	+0.0008	+0.0005
Middle	+0.0004	+0.0004
Bottom	+0.0002	+0.0004

Overall Average Change: +0.0004

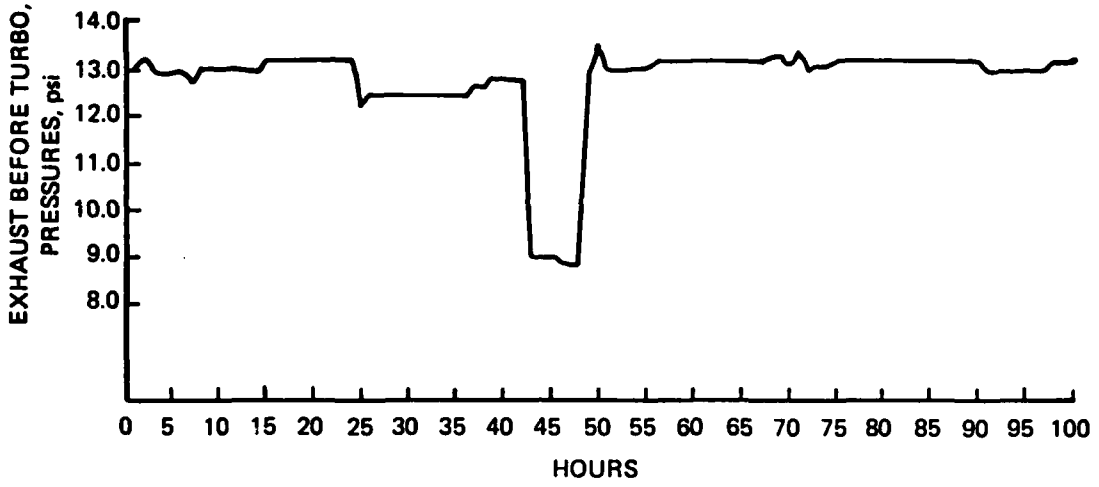
Piston Ring End Gap Change

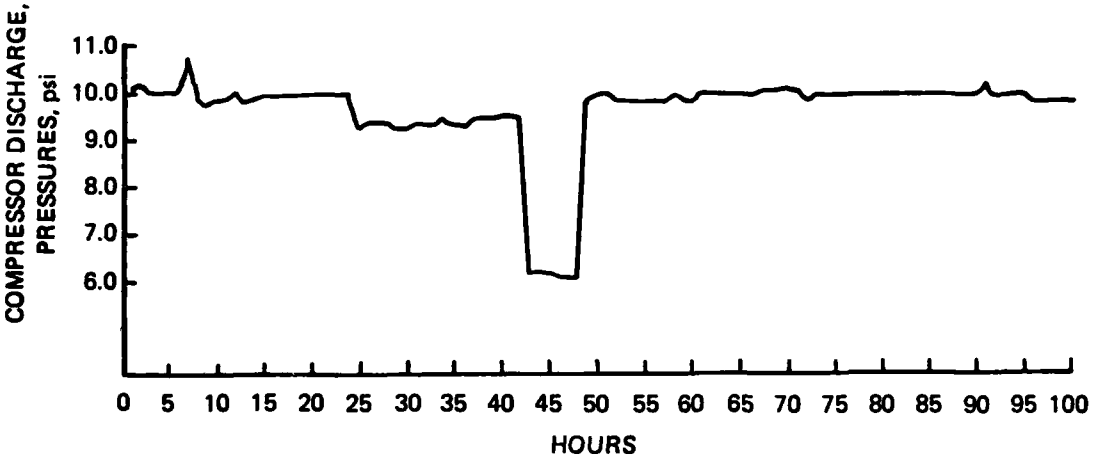
Ring Number	1L	2L	3L	1R	2R	3R	Average Change
1	+0.001	-0.001	+0.001	+0.001	-0.001	+0.001	+0.0003
2	-0.002	-0.001	0.000	-0.001	+0.001	-0.002	-0.0008
3	-0.001	-0.002	0.000	-0.001	0.000	+0.001	-0.0005
4	-0.001	0.000	-0.001	0.000	-0.002	-0.002	-0.0010
5	+0.002	+0.003	+0.003	+0.003	+0.006	+0.004	+0.0035
6	+0.001	0.000	+0.002	+0.001	+0.002	+0.002	+0.0013
7	0.000	+0.001	0.000	+0.001	+0.002	+0.002	+0.0010

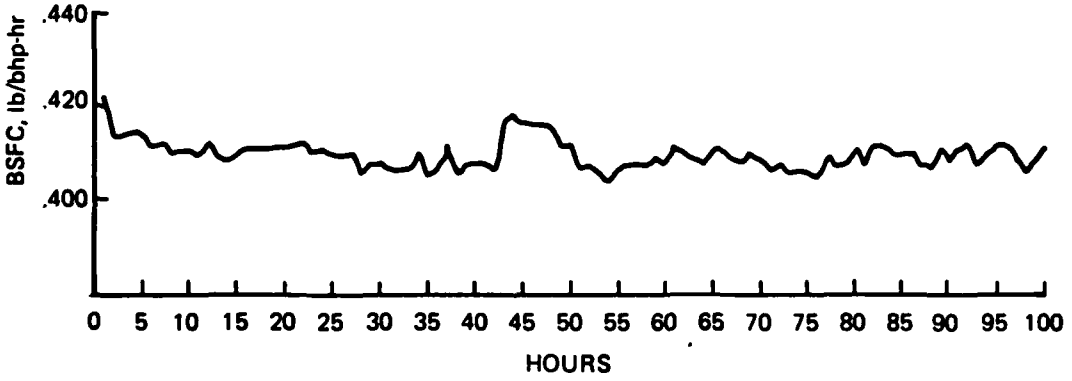
Overall Average Change : +0.0005

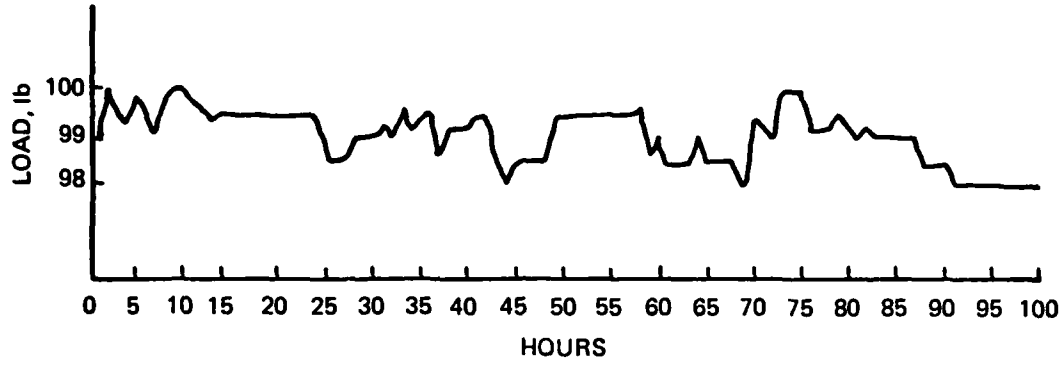
* All dimensions given are in inches.

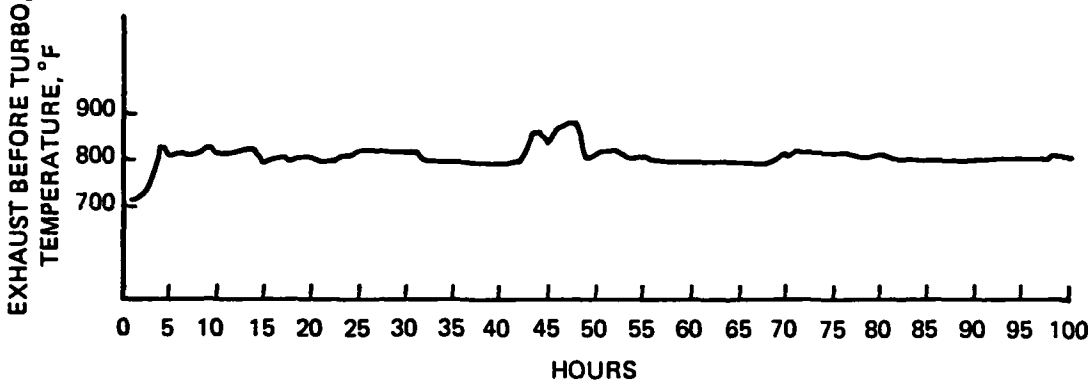
** T-AT= Thrust-Anti-thrust direction; F-B= Front-Back direction

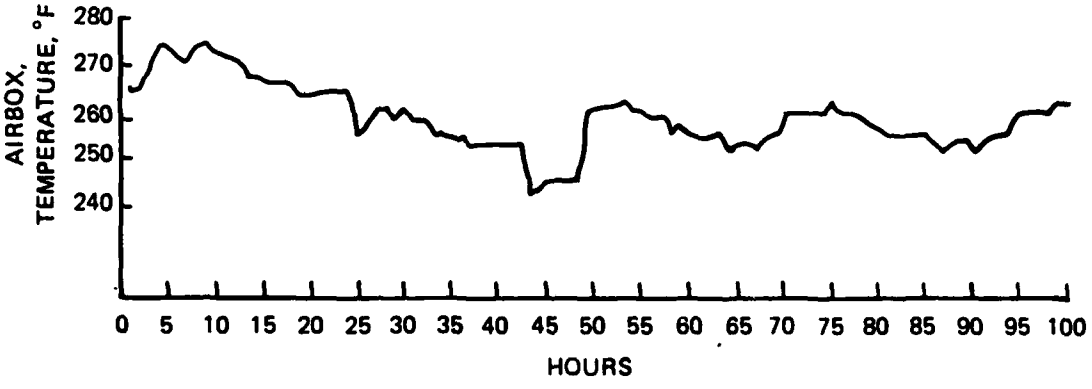

EXHAUST BEFORE TURBO, PRESSURES, psi
14.0
13.0
12.0
11.0
10.0
9.0
8.0
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
HOURS

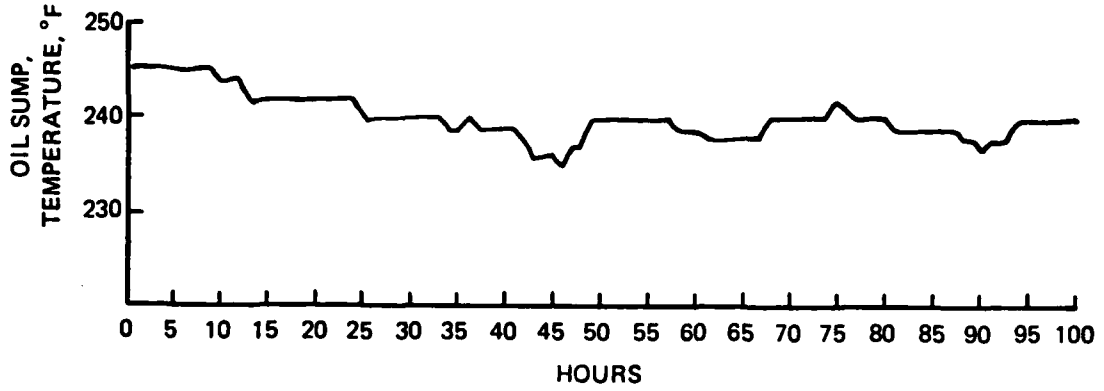

COMPRESSOR DISCHARGE, PRESSURES, psi
11.0
10.0
9.0
8.0
7.0
6.0
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
HOURS

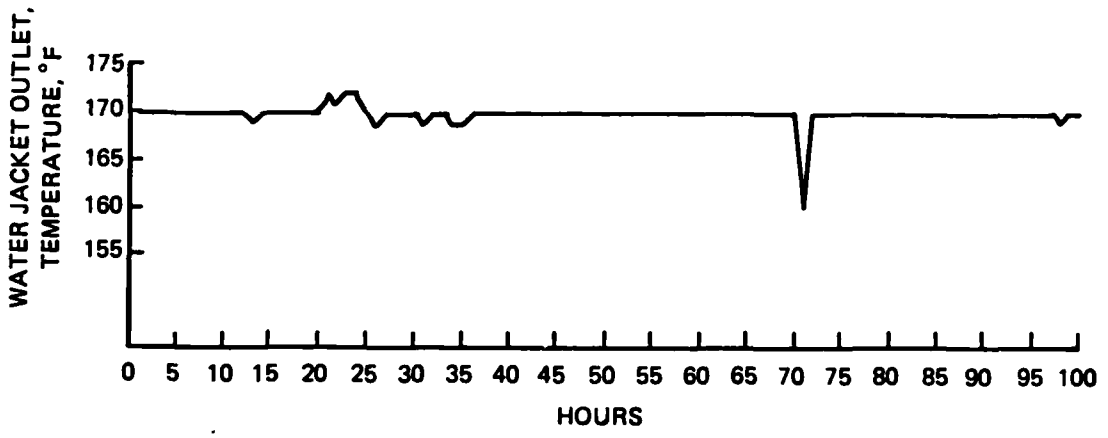

BSFC, lb/bhp-hr
.440
.420
.400
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
HOURS


LOAD, lb
100
99
98
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
HOURS


EXHAUST BEFORE TURBO, TEMPERATURE, °F
900
800
700
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
HOURS


AIRBOX, TEMPERATURE, °F
280
270
260
250
240
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
HOURS


OIL SUMP, TEMPERATURE, °F
250
240
230
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
HOURS


WATER JACKET OUTLET, TEMPERATURE, °F
175
170
165
160
155
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
HOURS

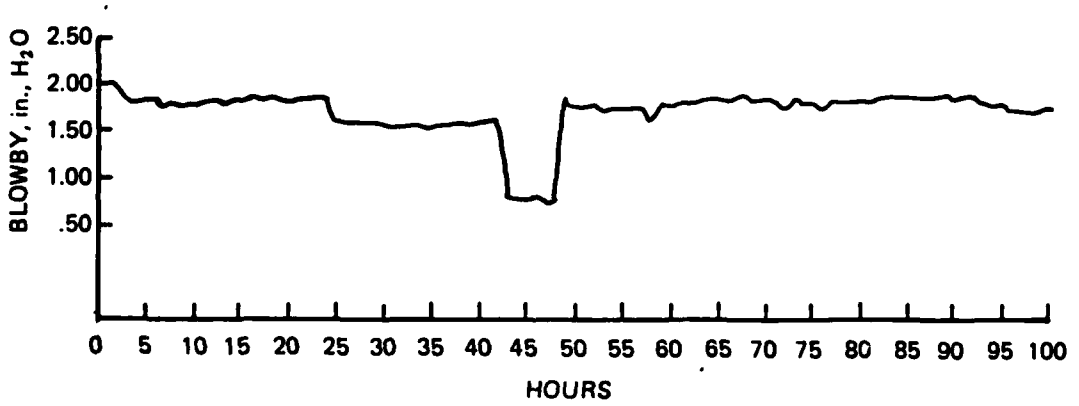
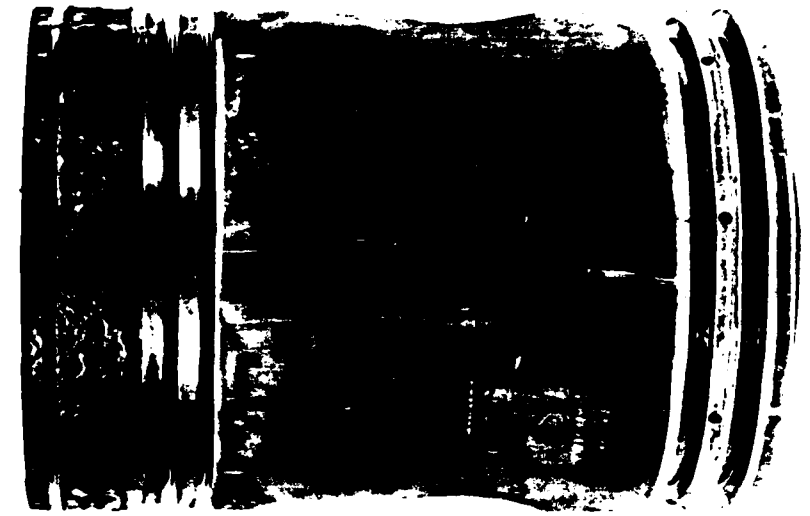
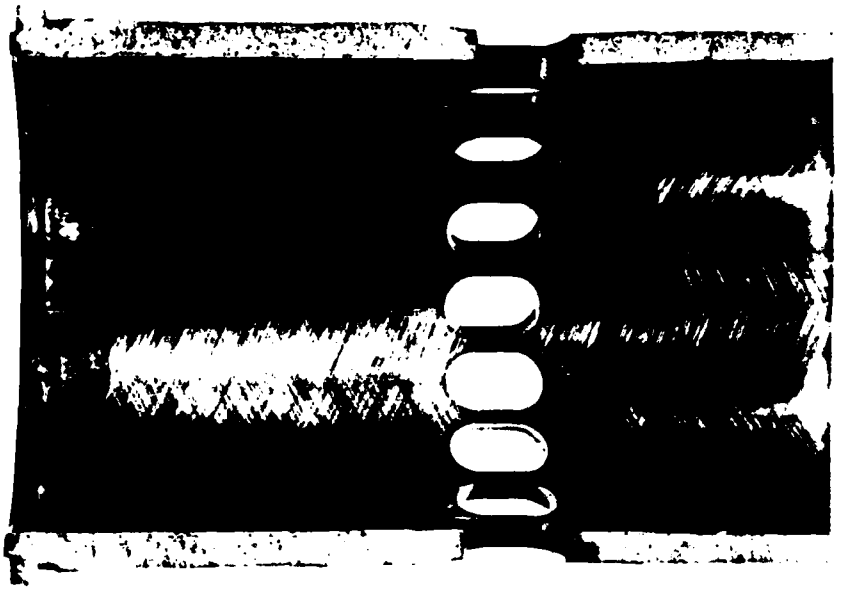

BLOWBY, in., H_2O
2.50
2.00
1.50
1.00
.50
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
HOURS

FIGURE 1. METHOD 354

Condition of Piston and Cylinder Liner

Test Time 100 Hours Test No. MTC-4 Lubricant: AL-10153-L



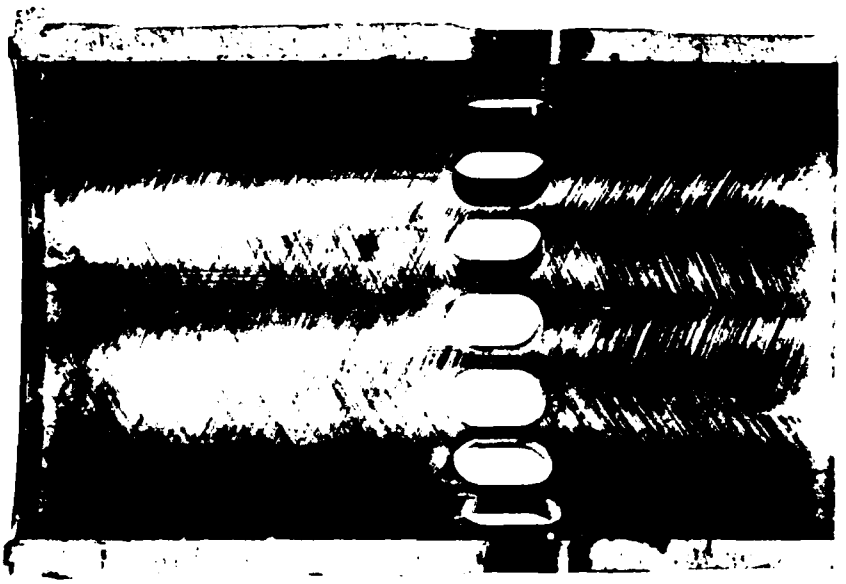


1 Right Thrust

Figure 2. METHOD 334

Condition of Piston and Cylinder Liner

Test Time 100 Hours Test No. MTC-4 Lubricant: AL-10153-L

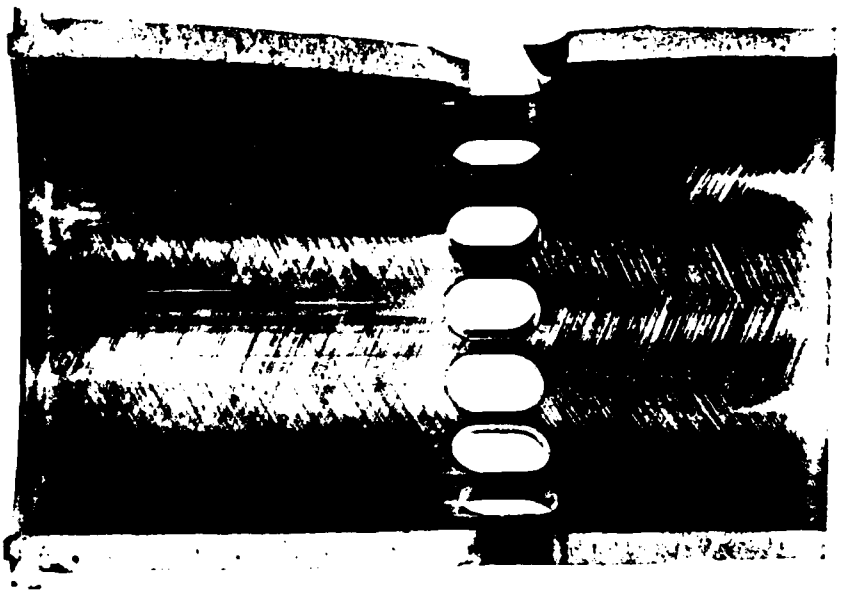


1 Right Antithrust

Figure 3. METHOD 354

Condition of Piston and Cylinder Liner

Test Time 100 Hours Test No. MTC-4 Lubricant: AL-10153-L

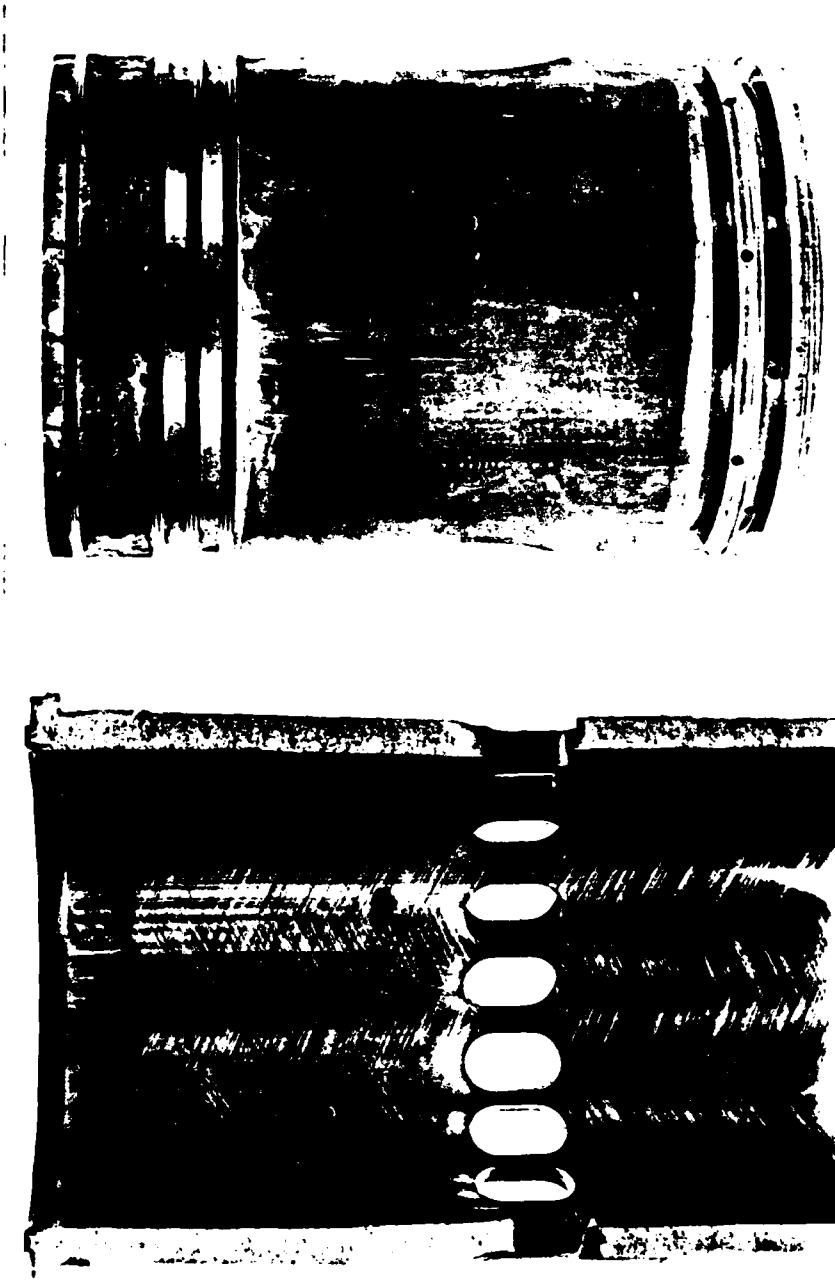


2 Right Thrust

Figure 4. METHOD 354

Condition of Piston and Cylinder Liner

Test Time 100 Hours Test No. MTC-4 Lubricant: AL-10153-L

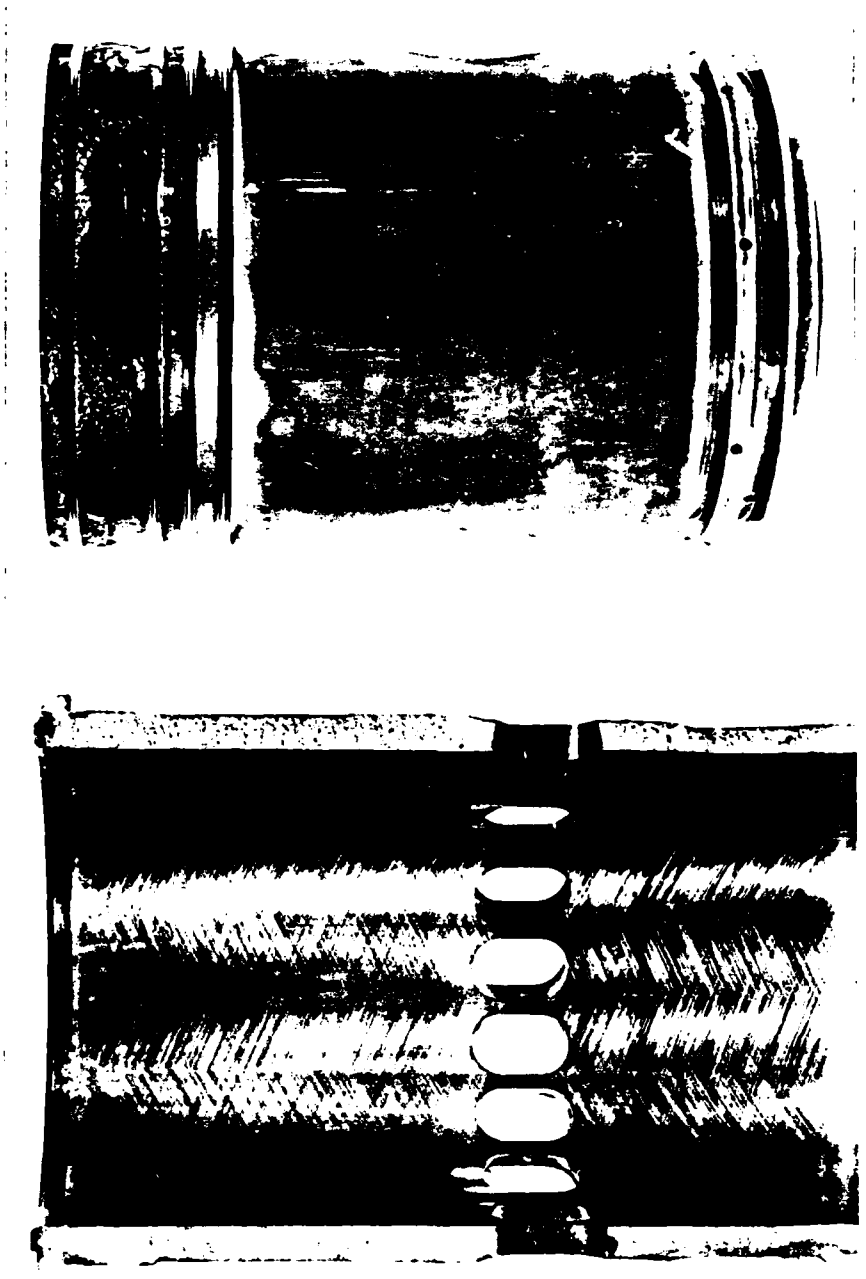


2 Right Antithrust

Figure 5. METHOD 2[illegible]

Condition of Piston and Cylinder Liner

Test Time 100 Hours Test No. MTC-4 Lubricant: AL-10153-L

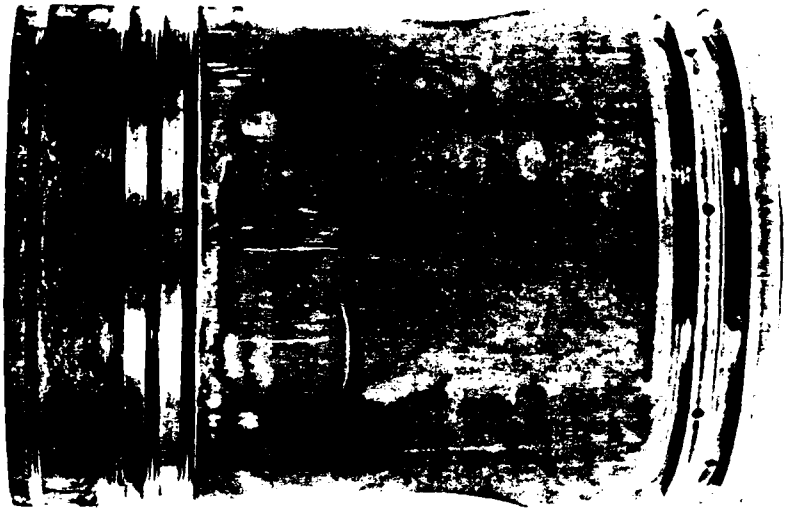


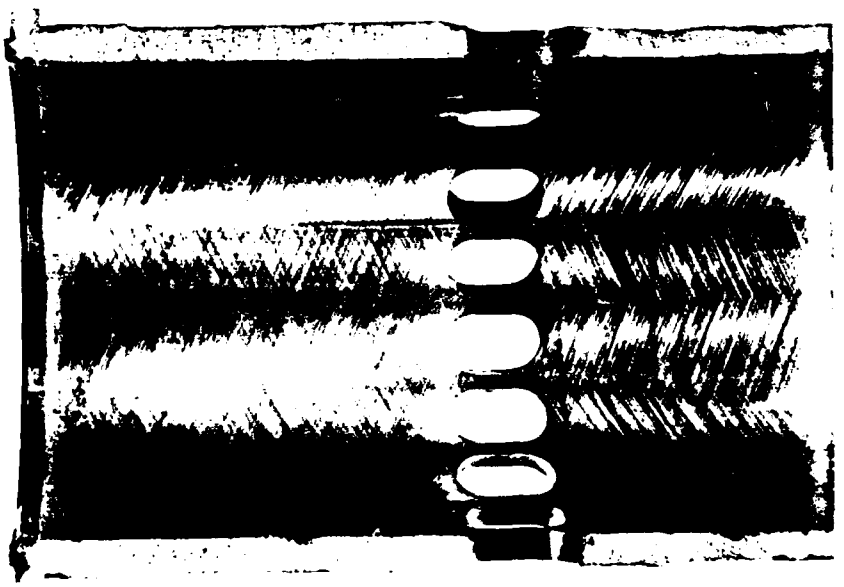
3 Right Thrust

Figure 6. MIL-H-5606

Condition of Piston and Cylinder Liner

Test Time 100 Hours | Test No. MTC-4 | Lubricant: AL-10153-L



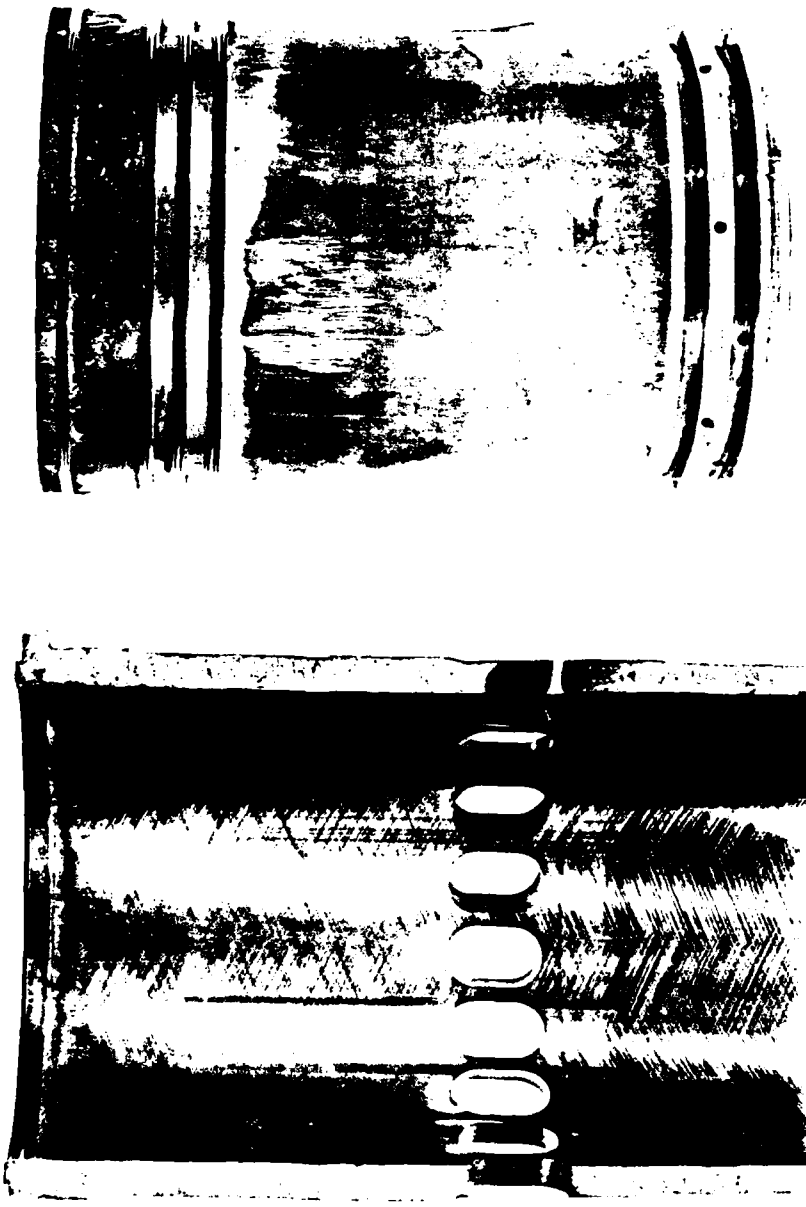


3 Right Antithrust

Figure 7. METHOD 335.

Condition of Piston and Cylinder Liner

Test Time 100 Hours | Test No. MTC-4 | Lubricant: AL-01053-L

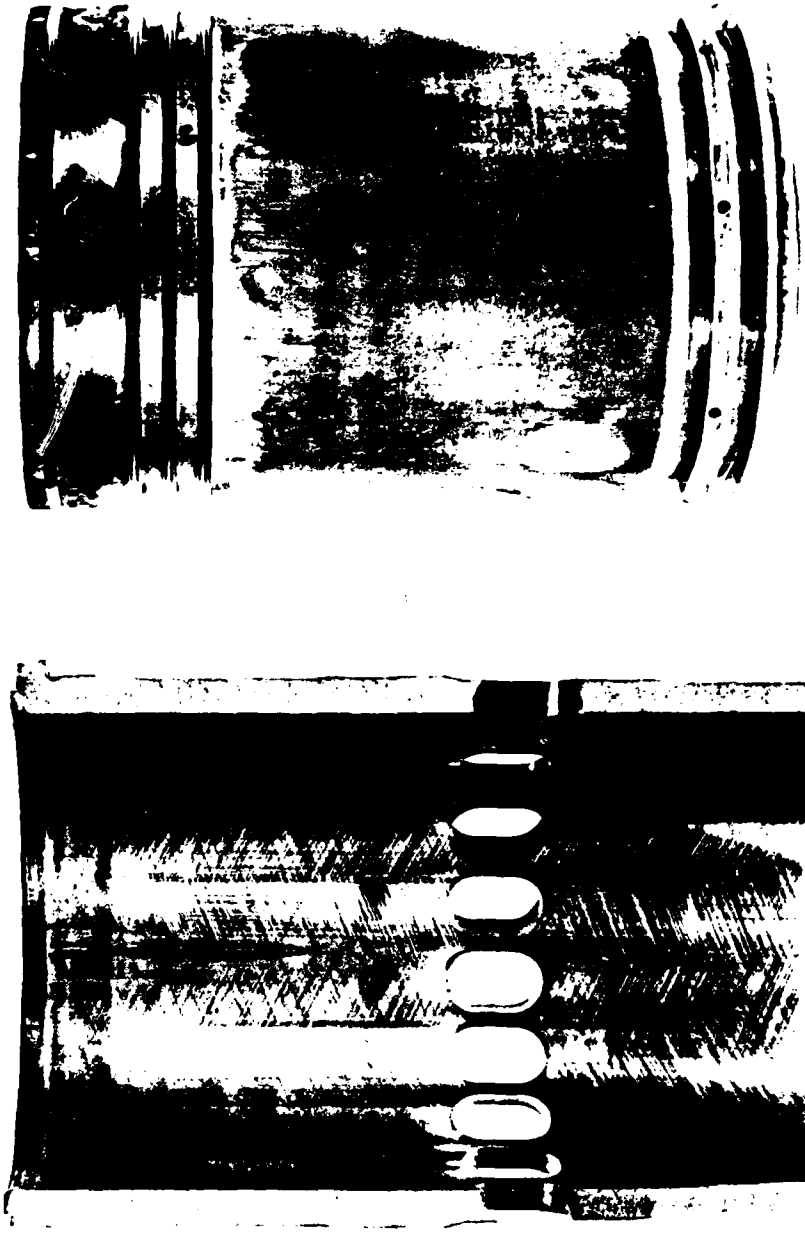


1 Left Thrust

Figure 3. METHOD 3354

Condition of Piston and Cylinder Liner

Test Time 100 Hours | Test No. MTC-4 | Lubricant: AL-10153-L

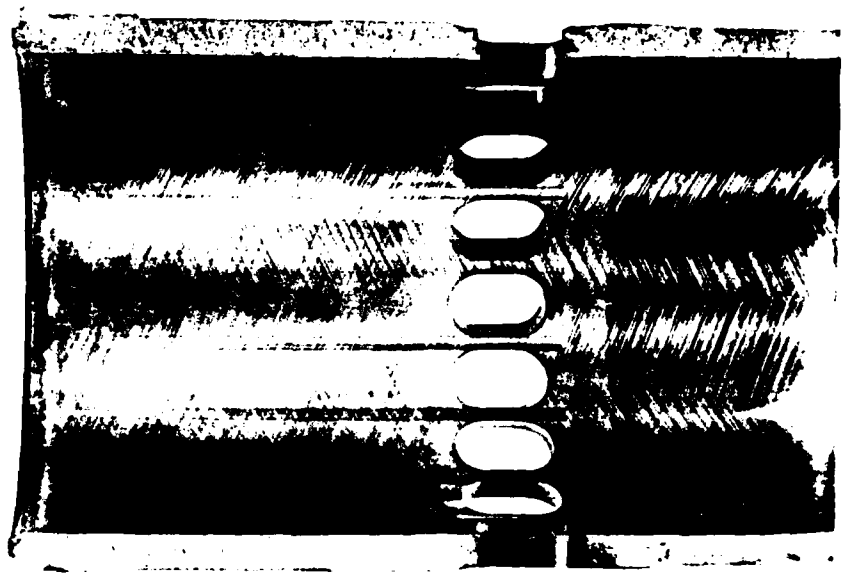


1 Left Antithrust

Figure 5. METHOD 3...

Condition of Piston and Cylinder Liner

Test Time 100 Hours | Test No. MTC-4 | Lubricant: AL-10153-L

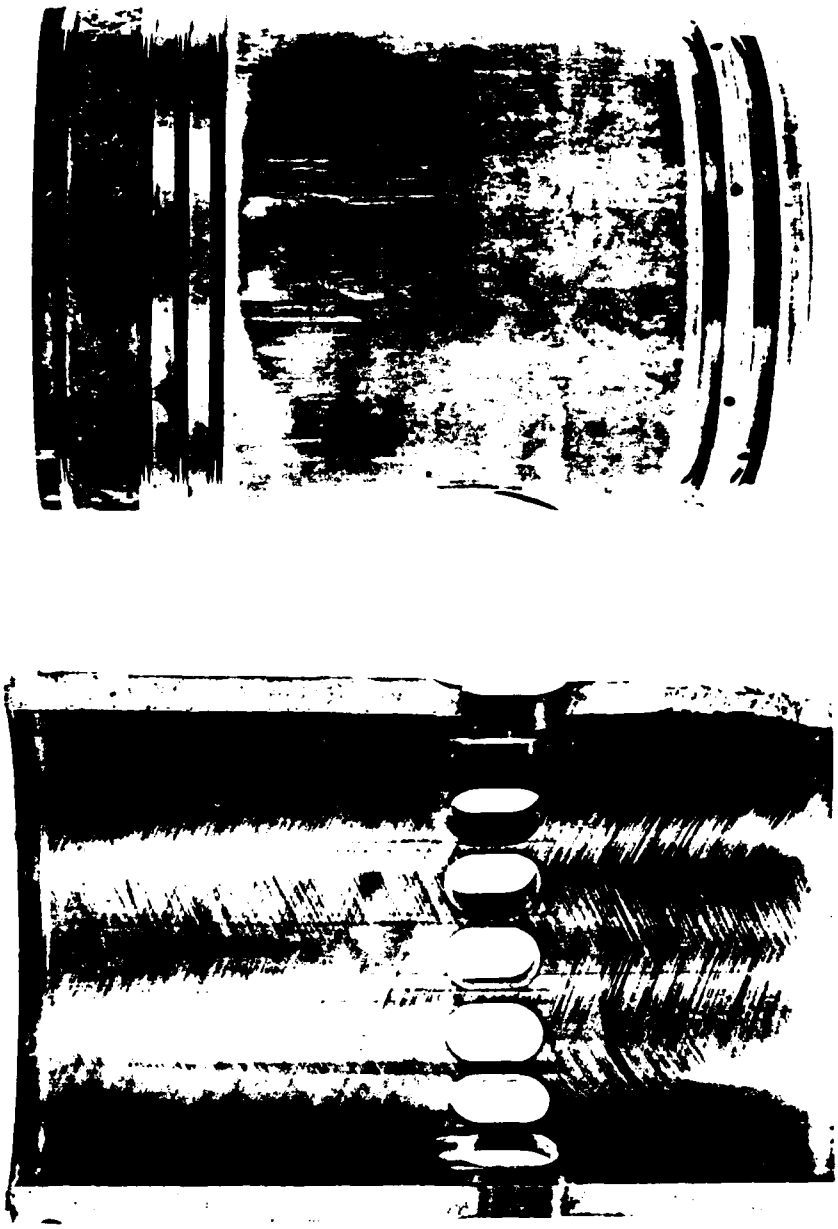


2 Left Thrust

Figure 19. METHOD 354

Condition of Piston and Cylinder Liner

Test Time 100 Hours | Test No. MTC-4 | Lubricant: AL-10153-L

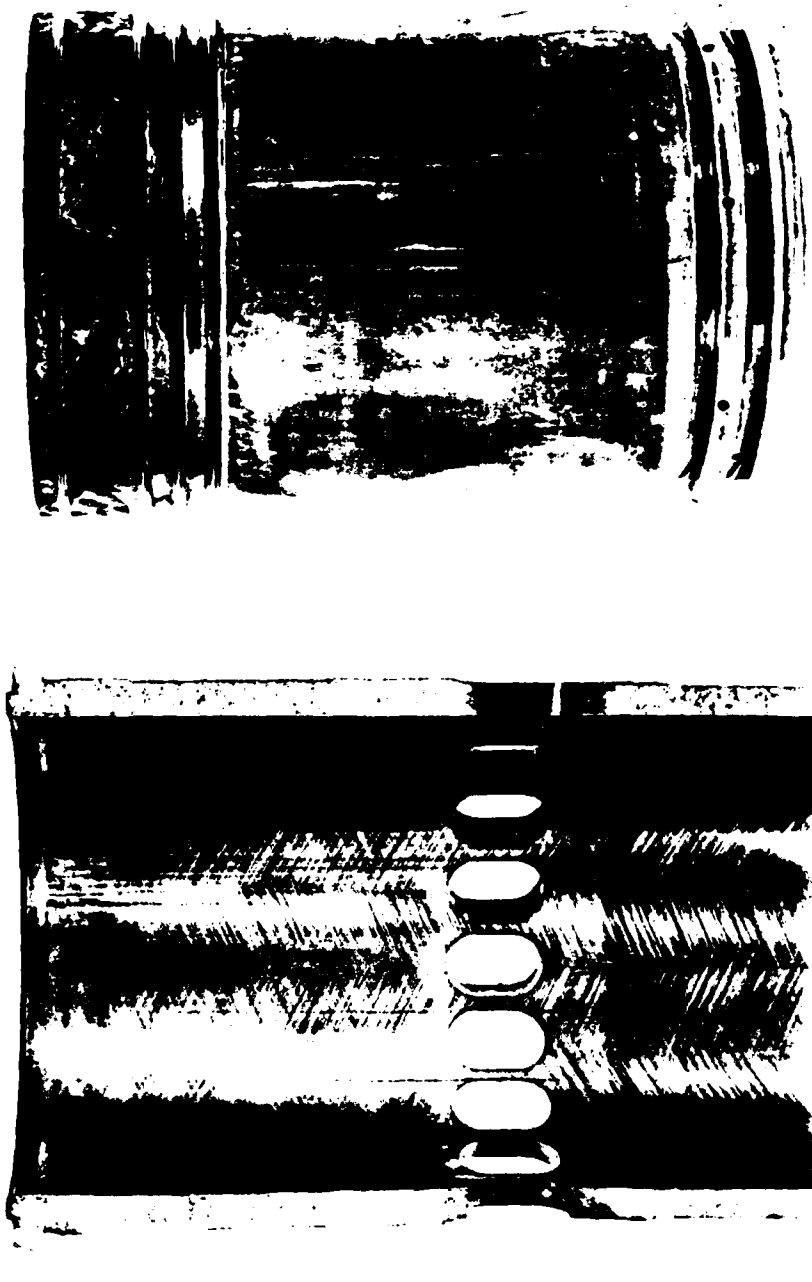


2 Left Antithrust

Figure 71. Micrographs of

Condition of Piston and Clyinder Liner

Test Time 100 Hours | Test No. MTC-4 | Lubricant: AL-10153-L

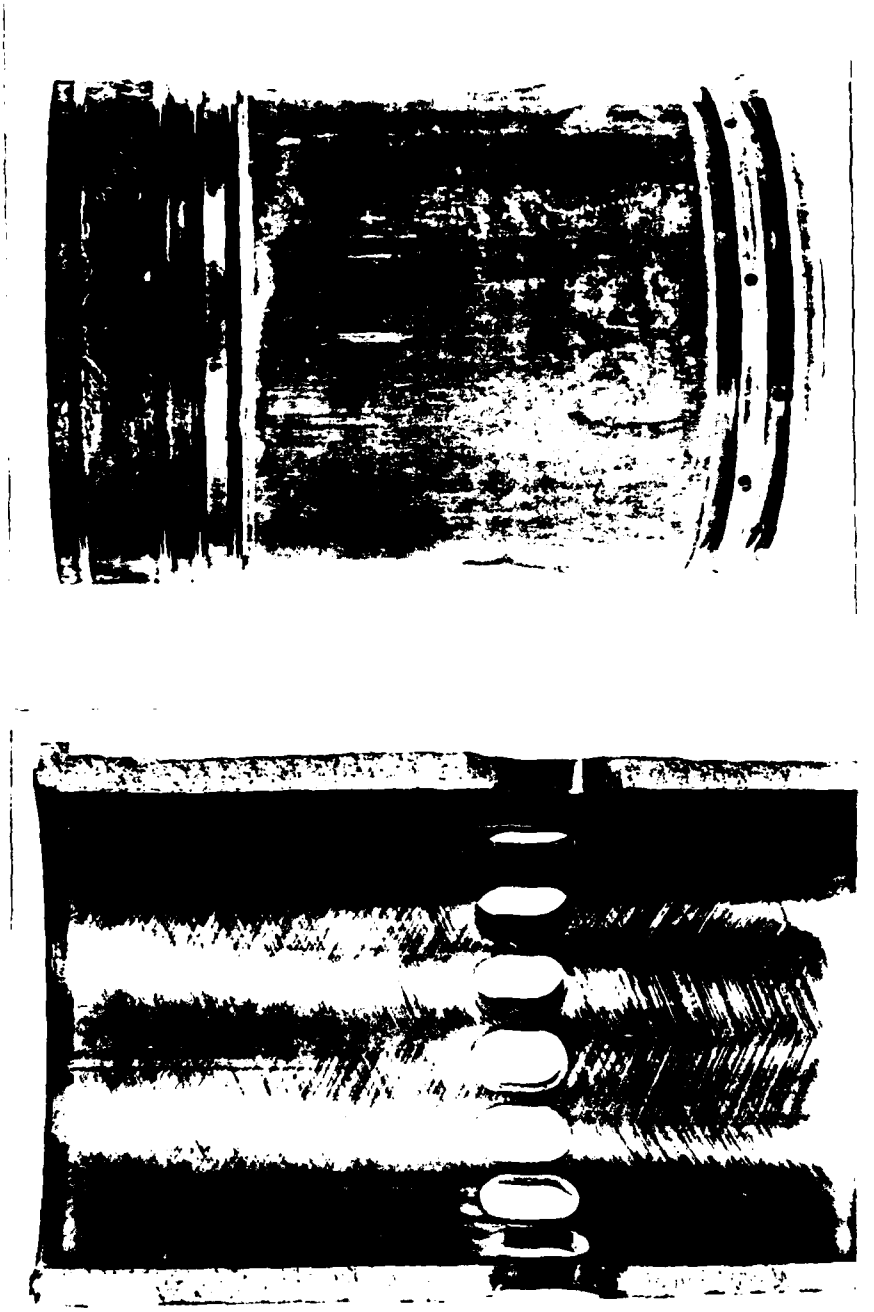


3 Left Thrust

Figure 12. METHOD 3.

Condition of Piston and Cylinder Liner

Test Time 100 Hours Test No. MTC-4 Lubricant: AL-10153-L

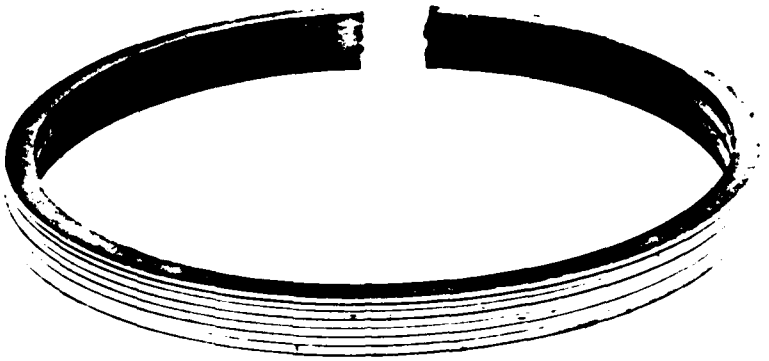


3 Left Antithrust

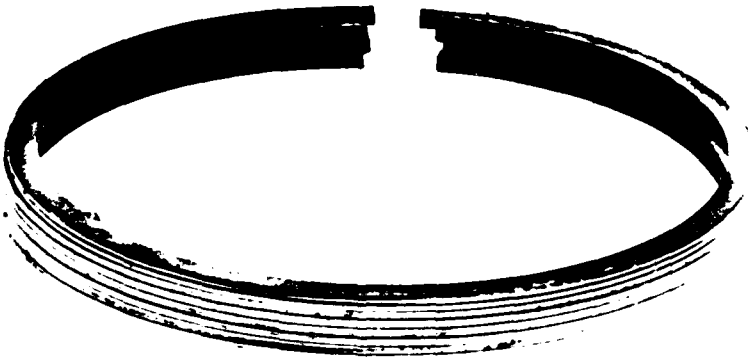
Figure 13. METHOD 354

Condition of Compression Ring Face

Test Time 100 Hours | Test No. MTC-4 | Lubricant: AL-10153-L



1 Right

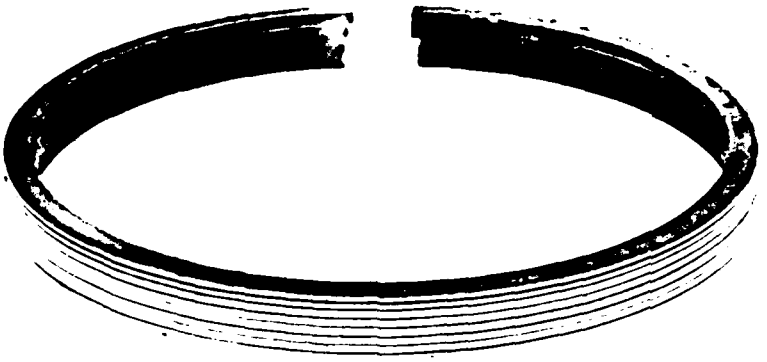


2 Right

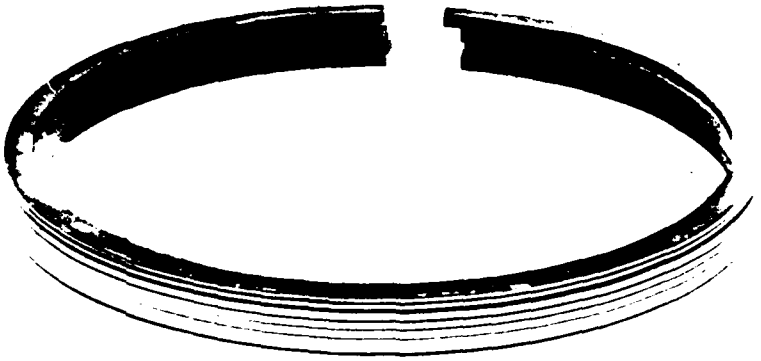
Figure 14. METHOD 3[illegible]

Condition of Compression Ring Face

Test Time 100 Hours | Test No. MTC-4 | Lubricant: AL-10153-L



3 Right

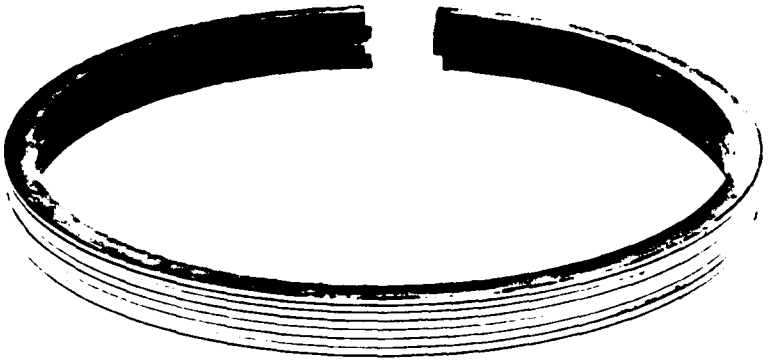


1 Left

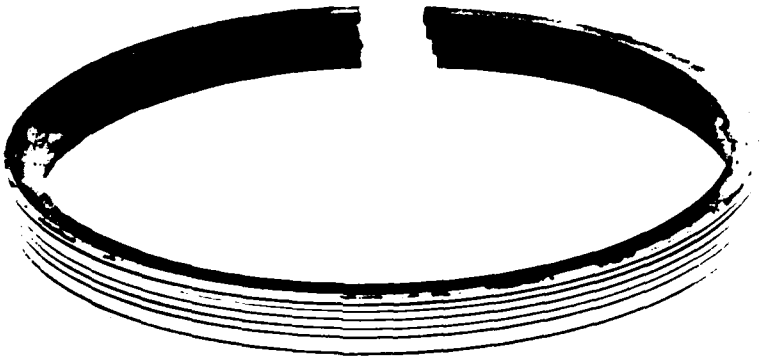
Figure 1. METHOD 35.

Condition of Compression Ring Face

Test Time 100 Hours Test No. MTC-4 Lubricant: AL-10153-L



2 Left



3 Left

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